UNIVERSITY OF SÃO PAULO
BIOSCIENCES INSTITUTE

ELISA MARI AKAGI JORDÃO

Is it possible to dissociate a voluntary process from a automatized process in endogenous orienting of attention in humans?

É possível dissociar um processo voluntário de um processo automatizado na orientação endógena da atenção em humanos?

São Paulo

2019

ELISA MARI AKAGI JORDÃO

Is it possible to dissociate a voluntary process from a automatized process in endogenous orienting of attention in humans?

É possível dissociar um processo voluntário de um processo automatizado na orientação endógena da atenção em humanos?

Ph.D. Thesis presented to the Graduate Program in Physiology at the Instituto de Biociências, Universidade de São Paulo, Brasil to obtain the degree of Doctor of Science

Concentration area: Physiology

Advisor: Prof. Dr. Gilberto Fernando Xavier

São Paulo

2019

Ficha catalográfica elaborada pelo Serviço de Biblioteca do Instituto de Biociências da USP, com os dados fornecidos pelo autor no formulário:
http://www.ib.usp.br/biblioteca/ficha-catalografica/ficha.php

Jordão, Elisa Mari Akagi
É possível dissociar um processo voluntário de um processo automatizado na orientação endógena da atenção em humanos? / Elisa Mari Akagi Jordão; orientador Gilberto Fernando Xavier. -- São Paulo, 2009.

118 f.

Tese (Doutorado) - Instituto de Biociências da Universidade de São Paulo, Departamento de Fisiologia.

1. Orientação endógena da atenção. 2. Voluntária. 3. Automatizada. 4. Tarefa de Posner. I. Xavier, Gilberto Fernando, orient. II. Título.

Bibliotecária responsável pela estrutura da catalogação da publicação:
Elisabete da Cruz Neves - CRB - 8/6228

Name: Elisa Mari Akai Jordão

Title: Is it possible to dissociate a voluntary process from a automatized process in endogenous orienting of attention in humans?

Thesis presented to the Graduate Program in Physiology at the Instituto de Biociências, Universidade de São Paulo, Brasil to obtain the degree of Doctor of science

Aproved in:

Exam Comitee

Prof(a). Dr(a). ____

Institution ____

Judgement ____

Prof(a). Dr(a). ____

Institution ____

Judgement ____

Prof(a). Dr(a). ____

Institution ____

Judgement ____

Prof(a). Dr(a). ____

Institution ____

Judgement ____

AGRADECIMENTO

À FAPESP (processo: 2014/22703-6), CAPES e aos brasileiros pagadores de impostos pelo apoio financeiro imprescindível para este estudo.

Ao Gilberto Xavier, pela orientação e por sempre me motivar a confiar mais em minhas ideias e meu trabalho.

Ao Ron Mangun, por ter me recebido com muita alegria e entusiasmo em seu laboratório em Davis, e me concedido a confiança e independência para realizar meus projetos.

Ao André Cravo, pela colaboração no projeto, disponibilização de seu laboratório e apoio no projeto sempre estando disponível para conversar.

À minha família, por todo apoio, emocional e material, sem os quais teria sido impossível finalizar esse projeto. Neucy, Gastão, Raquel, Felipe, e a mais nova membra da família, Zahara, vocês são a fundação sobre a qual consigo construir novos projetos.

Aos meus amigos, próximos e distantes, por me acompanharam nesses 5 anos de muita mudança, conflitos e felicidade. Um agradecimento especial às amigas da BioUsp, Babi, Fê, Sassa, Pacoca, Tal, Thais, que compartilham comigo desde 2006 muitas lutas e conquistas sem perderem a alegria.

Ao Marcelo, querido amigo, colega e programador, por ter sido meu companheiro acadêmico, a quem sempre pude recorrer para dúvidas estatísticas e existenciais.

Aos amigos dos laboratórios da Fisiologia, por tornarem o ambiente de trabalho muito produtivo e prazeroso. Em particular agradeço ao Mateus, Daniel e Pedro, queridos amigos que acompanhei e me acompanharam nessa decisão insana de realizar um doutorado. E um agradecimento especial ao LabCog, por terem me recebido tão bem no seu espaço físico (e nos seus corações) no meu último ano.

Às minhas amigas fisiológicas, Jaque, Bruna e Renata, responsáveis por manter o meu conhecimento além das neurociências, e por serem as fiéis companheiras das festas.

A todos do Departamento de Fisiologia e do IB-USP, aos colegas, aos técnicos, às secretárias e aos professores, por possibilitarem uma convivência profissional intelectualmente enriquecedora.

“From an external, socially organized attention develops the child’s voluntary attention, which in this stage is an internal, self-regulating process.”

– Vygotsky L.S.

RESUMO

JORDÃO, E. M. A. É possível dissociar um processo voluntário de um processo automatizado na orientação endógena da atenção em humanos? 2019. 118f. Tese (Doutorado) - Instituto de Biociências, Universidade de São Paulo, São Paulo, 2019.

Considera-se que a orientação da atenção ocorre pelo menos de duas formas distintas, i.e., exogenamente (ou orientação reflexiva) ou endogenamente (ou orientação voluntária). No entanto, evidências sugerem que a orientação endógena da atenção poderia envolver tanto processos voluntários como também processos automatizados. O principal objetivo dos três estudos aqui relatados foi diferenciar, comportamental e eletrofisiologicamente, o curso temporal da orientação endógena da atenção envolvendo processos voluntários e automatizados. Os experimentos foram delineados para investigar os efeitos da orientação voluntária da atenção evitando-se a possibilidade de automatização usualmente observada após apresentação contígua repetitiva de uma pista com um alvo. Para isso, foram criadas duas variantes da tarefa clássica de Posner. No primeiro capítulo a tarefa consistia em apresentar um estímulo visual relevante entre a apresentação da pista e do alvo para evitar a contiguidade desses estímulos. Os resultados indicaram que a orientação voluntária da atenção parece ocorrer somente em intervalos de tempo mais longos do que 150 ms enquanto que a orientação automatizada ocorre em intervalos de tempo tão curtos quanto 150 ms. Na tarefa do segundo capítulo a pista simbólica era modificada a cada tentativa sendo necessário uma nova interpretação de seu significado espacial e evitando, assim, a apresentação repetitiva de uma só pista seguida do alvo em um local. Observou-se que quando há um conflito na interpretação da pista a orientação voluntária da atenção é prejudicada, porém ainda podendo ocorrer em intervalos de tempo de 250 ms. Esse prejuízo na orientação da atenção estaria relacionado com uma diminuição da decodificação do alvo na memória visual operacional demonstrado pelos resultados eletrofisiológicos. De modo distinto, no capítulo três, foi investigado o curso temporal necessário para processos automatizados e voluntários da orientação da atenção utilizando diferentes tipos de pistas como flechas, formas geométricas associadas a direcionamentos da atenção no espaço, e uma pista de escolha a qual o sujeito era livre para escolher qual lado orientar sua atenção. Foi observado que o curso temporal da orientação da atenção é similar para processos envolvendo pistas associadas a locais e pista de escolha, e podem ocorrer em intervalos de tempo de 200 ms. Porém, a orientação da atenção automatizada por um aprendizado de longa duração como o caso das flechas apresenta um curso temporal muito mais curto. Assim, os resultados indicam que a orientação da atenção voluntária mesmo sem a interferência de processos automatizados pode ocorrer em intervalos de tempo mais curtos do que o esperado. Isso se daria devido a uma facilitação da realização da tarefa, a qual estaria relacionada com contingências bem estabelecidas na tarefa e a presença de muitas repetições permitindo que mecanismos de aprendizagem reforcem o desempenho. A partir dessas evidências, uma hipótese teórica foi estruturada em torno da ideia de que as distinções de uma orientação endógena automatizada (rápida e fácil) ou voluntária (lenta e custosa) estariam relacionadas ao fortalecimento da associação entre a pista e o local indicado que varia em um continuum a partir de mecanismos de reforço que dependeriam da função dos componentes da memória operacional e sua conexão com a memória de longo prazo.

Palavras-chave: Orientação endógena da atenção. Voluntária. Automatizada. Tarefa de Posner

ABSTRACT

JORDÃO, E. M. A. Is it possible to dissociate a voluntary process from a automatized process in endogenous orienting of attention in humans? 2019. 118f. Thesis (PhD) - Biosciences Institute, University of São Paulo, São Paulo, 2019.

Orienting of attention is considered to occur at least in two distinct ways, i.e. exogenously (or reflexive) or endogenously (or voluntary). However, evidence suggests that endogenous orienting of attention could involve both voluntary and automatized processes. The main objective of the three studies reported here was to differentiate, behaviorally and electrophysiologically, the temporal course of a voluntary process from an automatized process involved in endogenous orienting of attention. The experiments were designed to investigate the effects of voluntary orienting of attention when avoiding the possibility of an automatization usually observed after repetitive contiguous presentation of a cue and a target. For this, two variants of the classic cueing task were created. In the first chapter the task consisted of presenting a relevant visual stimulus between the cue and target presentation to prevent the contiguity of these stimuli. The results indicated that voluntary shift of attention appears to occur only at time intervals longer than 150 ms while automatized orienting occurs at times as short as 150 ms. For the task on the second chapter the symbolic cue was different for each trial requiring a new interpretation of its spatial meaning, and thus avoiding repetitive presentation of a single cue followed by the target at a location. It was observed that when there is a conflict in the interpretation of the cue the voluntary orienting of attention is impaired, but may still occur at a time interval of 250 ms. This impairment in shifting attention would related to a decrease in target decoding in working visual memory demonstrated by electrophysiological results. Moreover, chapter three investigated the time course required for automatized and voluntary orienting of attention processes using different types of cues such as arrows, geometric shapes associated with direction of attention in space, and a choice cue to which the subject could freely choose which side to direct her attention to. It was observed that the time courses of orienting attention are similar for processes involving cues associated with locations and choice cue, and may occur at time intervals as short as 200 ms. However, an automatized orienting of attention triggered by arrow cues has a much shorter time course. Thus, the results indicate that voluntary orienting of attention even without the interference of automatized processes can occur at shorter time intervals than the expected. This would be due to a facilitation of task performance related to a well-established contingencies in the task and the presence of many repetitions allowing learning mechanisms to reinforce processes involved on the task. From these evidences, a theoretical hypothesis was structured around the idea that the distinctions of an automatized endogenous orientation (fast and effortless) or voluntary (slow and effortful) would be related to the strengthening of the association between the cue and the indicated location that varies on a continuum from reinforcement mechanisms that would depend on the function of working memory components and their connection to long-term memory.

Keywords: Endogenous orienting of attention. Voluntary. Automatized. Visuospatial cueing taks

Summary

1. Introduction

Picture yourself hiking on a trail in the amazon. It is a very dense forest, with tall trees, lower bushes, plants with thorns, army-ants on the ground, mosquitoes flying, you hear different birds communicating, and you see one or two tiny and colorful frogs jumping in the middle of the trail. If you are a biologist, or anyone who enjoys nature, you can get overwhelmed with so much information that you want to perceive. But suddenly you hear a loud noise on your right side. You turn around, try to see what it was, but nothing. After a few minutes, with no clue of what it was, you decide to keep walking. However, for the rest of the trail you won't be so interested in all things you encounter along it. Because, now, you are paying attention to your right side almost all the time waiting for another loud noise to happen. That's when you stumble in a tree root.

This brief story describes how attention is relevant to trivial tasks that we conduct in daily life, and how perception, memory and attention are intricately related. Attention is important to perceive sensory information. If a regular information is not attended, likely it will not be processed by the nervous system and will not be perceived. An example is the tree root that you stumble when you were not attending to the ground. However, if an information is attended, or a source of information is attended, then it will probably be processed as a priority in detriment of other information, as exemplified by your right side location after you heard the loud noise. This is also a good example of a relevant relationship involving attention and memory. After the loud noise, your right side location became a relevant source of information, perhaps because of fear or pure curiosity. Therefore, directing your attention to this location will happen often. This expectancy-dependent control of where attention is located is considered a voluntary process. Think about how many times you orient your attention to relevant locations when driving. As a novice driver you probably took longer to get to places, checked your mirrors, were very careful with pedestrians and traffic lights. However, after a few months driving you probably did all those things much faster, and even without being completely aware of them. Is it possible that your control of orienting of attention involved voluntary processes of each component of driving at the beginning, but after a lot of repetitive training it became automatized.

These questions permeate this thesis. The studies presented here investigated how voluntary, slow and effortful, and automatized, fast and effortless, processes contribute for endogenous orienting of attention from behavioral and electrophysiological perspectives.

1.1. Selective attention

According to Anne Treisman (1969), “attention can be defined as the selective aspect of perception and response”. In this sense, selective visual attention can be regarded as a set of processes that prioritize sensory processing of one or a few task-relevant items in a scene while also inhibiting irrelevant or distracting stimuli. The underlying assumption for this idea is that because the central nervous system has a limited capacity for sensory and/or response processing, in order to deal with the abundance of simultaneous information provided by the environment one requires selective mechanisms that facilitate processing of some information and/or inhibits processing of other information (Broadbent, 1982; Treisman, 1969; Theeuwes, 1992). Theories of selection are mainly concerned with how this selection occurs. One relevant aspect that received a lot of attention was in which moment of sensory processing the selection occurs.

Broadbent (1958) tested performance of humans in recollecting auditory and visual items of information presented simultaneously. He observed that performance was superior when the subjects adopted a strategy of attending and recalling all the items on one sensory modality, and then all items on the other sensory modality. He argued that because the two simultaneous stimuli were separated in sensory terms they could both be processed forming a representation internally without loss of data. However, for that to happen, stimuli had to be further processed from a first memory-stage to a later information processing going through a filter. To efficiently recall all items this filter would select items for the next stage of processing based on sensory properties of the input. Thus, for instance, visual items would be selected for further processing while auditory items would stay in a buffer storage until they could also be processed. From this and other studies, Broadbent theorized that when the system is overloaded there would be a “filter” that would relieve the system by limiting the transfer of information from a peripheral memory stage to later stages of processing. This proposal is considered part of the “early selection” theories of information processing. Afterwards, Treisman (1960) showed that even when attending to one stream of items, recollection of items from the other stream and of the same sensory modality could happen if their meaning were relevant for the current task. This led researchers (e.g., Deutsch & Deutsch, 1963) to propose and support a “late selection” theory of information processing, that suggests that selection occurs later in the internal processes after all stimuli reaching the senses had been fully processed. However, one well accepted view of selection is that some features of unattended information are processed and influence responses when those features are congruent with the current information being attended. Therefore, information not receiving priority for processing is attenuated but can reach full processing (or be prioritized) when relevant for the task being conducted (Treisman, 1964).

In consonance with this latter view, the “feature-integration” theory (Treisman & Gelade, 1980) for visual selective attention tries to explain how the nervous system deals with two or more objects in a visual input. According to this proposal, a pre-attentive stage of processing discriminates simple features in parallel, without focal attention. This explains why there is no set size effect, i.e. the increase amount of distractors does not increase target detection latencies, in a visual set with single-feature distinct target among distractors. However, when the target does not have a single-feature distinction from distractors, its detection latency increases linearly with set size. Thus, the theory proposes that integration of a conjunction of features into a single combined unit can only occur serially, one item at a time, in the attentive process. This serial process involving each item being scanned one at a time is congruent with the effect of set size when target is not salient and a conjunction of features requires processing. However, other models oppose to this view. For instance, Desimone & Duncan (1995) favored the notion of a parallel processing system with selection occurring at later stages by a limited capacity system. Other models and theories also tried to make sense of data related to visual selective attention, favoring the notion that both processing mechanisms are involved, running in parallel at early stages and serially at later stages (Theeuwes, 1993; Luck & Hillyard, 1990; Tamber-Rosenau & Marois, 2016).

Control of orienting of visual attention is also a major aspect under investigation. According to the proposal of automatic and controlled processes of selection introduced by Schneider & Shiffrin (1977), “automatic processing is generally fast, parallel, fairly effortless, not limited to short-term memory capacity, not under direct subject control, and performs well-developed skilled behaviors” (p. 269). This type of processing would occur after extensive training involving consistent pairings of stimuli over many trials. In visual search tasks, for instance, when target and non-target are constant remaining the same from trial to trial, the speed of search does not depend on the set size. In contrast, “controlled processing is often slow, generally serial, effortful, capacity limited, subject regulated, and used to deal with novel or inconsistent information” (p. 269). Usually, controlled processing is required when targets and non-targets change from trial to trial (or in the beginning of the search task), thus with instructions guiding search and non-targets interfering with search. In this case, increase in the number of items results in decreased speed of processing. Further, the authors suggest that a complex combination of both processes would be present in all tasks. Many studies involving different attentional tasks, some of which will be reported here, have employed similar frameworks to explain distinctions between different perceptual and response processes.

Spatial attention plays an important role in visual attention. Not only ‘what’, but also ‘where’ objects are selected from are subjected to specific processes. An object or its visual scene is better detected and processed if presented at an attended location while processing of stimuli outside the focus of attention is worst (Eriksen & Hoffman, 1972; Posner, 1980). This can be revealed experimentally by orienting attention to a particular location and comparing the response to a stimulus presented at this location relative to a stimulus presented at another location. Consistently, the response to the attended stimulus is faster and more accurate than the response to the unattended stimulus. Further, as mentioned above, evidence shows that orienting of attention can also involve voluntary or automatic processes.

Sherrington, in 1906, described reflex and volitional actions in “The integrative action of the nervous system”, as it follows:

> “Yet it is clear, in higher animals especially so, that reflexes are under control. Their intrinsic fatality lies under control by higher centres unless their nervous arcs are sundered from ties existing with those higher centres. In other words, the reactions of reflex-arcs are controllable by mechanisms to whose activity consciousness is adjunct. By these higher centres, this or that reflex can be checked, or released, or modified in its reaction with such variety and seeming independence of external stimuli that the existence of a spontaneous internal process expressed as "will" is the naive inference drawn. (...) It is urgently necessary for physiology to know how this control—volitional control—is operative upon reflexes, that is, how it intrudes and makes its influence felt upon the running of the reflex machinery. How is the cough, or eye-closure, or the impulse to smile suppressed? How is the convergence of the eyeballs, innately associate to visual fixation of a near object initiated voluntarily without recourse to fixation on an object? (…) No exposition of the integrative action of the nervous system is complete, even in outline, if this control is left without consideration. Reflexes ordinarily outside its pale can by training be brought within it (...) Volitional movement can certainly become involuntary, and, conversely, involuntary movements can sometimes be brought under subjection to the will.” [p. 388-389]

Although his considerations relate to control of action, it seems possible to extend this idea for the control of spatial attention. Because orienting, shifting or deploying attention is commonly regarded as a movement of the attentional focus even without an actual muscle movement (Posner, 2016). Definitions and conceptualizations of what is voluntary or automatic seldomly fall into the problem of being vague by using other unclear concepts like “conscious” or “intentions” for something voluntary, and “unconscious” or “unintended” for automatic (Kimble & Perlmuter, 1970). Therefore, a rather more neurophysiological, and thus mechanistic, approach to these concepts will be adopted for the most part of the discussions mentioned here.

1.2. Visuo-spatial orienting of attention

Orienting of attention will be considered to occur in two main forms: one reflexive (termed exogenous orienting or bottom-up) and the other voluntary (termed endogenous orienting or top-down). These two forms of attention were experimentally dissociated and have proper and conspicuous characteristics (Posner & Cohen, 1984). In a seminal study reported in 1980, Posner used either symbolic stimuli (arrows presented close to the fixation point) or peripheral stimuli (abrupt changes in the luminance of lines surrounding the place for later target presentation) to indicate, either validly (correctly) or invalidly (incorrectly), the likely location for appearance of an impending visual target. All along the task, the subjects gazed in a single fixed location; thus, attention was oriented covertly. The idea was to investigate how orienting of attention validly and invalidly towards cued locations would affect target detection, minimizing the contribution of either sensory or motor aspects. By measuring the reaction time (RT) and/or accuracy to the target presentation it seemed possible to quantify the benefit promoted by valid cues and costs promoted by invalid cues associated to orienting of attention.

Studies using this basic experimental arrangement, referred here as classical cueing task, allowed characterizations of how shifting attention in a visuo-spatial area is controlled [Posner & Cohen, 1984; Jonides, 1981; Muller & Rabitt, 1989; see Klein (2009) for review]. Exogenous orienting of attention is triggered a salient stimulus, usually a brief change in luminance in the lines composing a square surrounding the place where the target is to be presented, called peripheral cue, usually located at 7o to the left or the right of the fixation point, in the horizontal plane, followed by the target stimulus, which may appear at the same location (when the cue is valid) or at opposite location (when the cue is invalid). For endogenous attention, a symbolic cue (also named central cue, e.g., an arrow or a geometric figure) typically presented close to the fixation point indicates the likely target location. In both cases, the time interval between the beginning of the cue and the beginning of the target (Stimulus Onset Asynchrony or SOA) is varied from trial do trial thus delimiting the time interval available for orienting of attention (Chica *et al.*, 2014). Moreover, a relevant condition of the task is relative to the predictiveness of cues along trials, i.e. how informative they are about the actual location of the target. A non-predictive condition consists of 50% of trials with cues indicating target location correctly or incorrectly, which means no informative relationship between cue and target. When this frequency is different from 50% (e.g. 80% of trials with cues indicating correctly the location of target) then the task condition is predictive, i.e. cues are informative about the likely target location. is considered to delimit the time provided for orienting of attention processes to occur (Chica *et al.*, 2014). Combinations of cue nature (either symbolic or peripheral), cue predictiveness (either predictive or non-predictive) and cue validity (either valid or invalid), all associated with the SOA, have provided means to characterize different processes of orienting of attention (see Luck & Vecera, 2002, for review).

For instance, symbolic non-predictive cues does not induce any validity effect (i.e. the reaction time in invalid trials minus the reaction time in valid trials) because cue-target relationship would not be informative, thus the subject would not know or use the direction that the cue is indicating. In contrast, predictive symbolic cues reduce RT for valid cued targets as compared to invalid cued targets at SOAs longer than 300 ms, with a long lasting period of a few seconds. The explanation for the presence of validity effect only at longer SOA is that symbolic cues need to be interpreted in order to orientation to occur properly. Therefore, it would involve slow and effortful processes related to endogenous orienting of attention (Jonides, 1981; Muller & Rabbitt, 1989). Peripheral cues are related to distinct behavioral results. Even when peripheral cue is non-predictive valid cues reduce reaction times to the target as compared to invalid cues, usually at SOAs as short as 50 ms (Castro-Barros *et al*., 2008). This fast effect is ascribed to exogenous capture of attention by the peripheral non-predictive cues. However, this positive validity effect is observed only until SOAs of 300 ms. SOAs longer than 300 ms produce higher reaction times for valid as compared to invalid cued targets, i.e. negative validity effect, an effect termed as Inhibition of Return - IOR (Posner *et al.*, 1985). This effect is explained as a prioritization of unattended locations in detriment of locations already attended recently without meaningful events (Posner & Cohen, 1984). These results are interpreted as the involvement of a fast and effortless processes, related to exogenous orienting of attention, at SOAs shorter than 300 ms. In contrast, for peripheral predictive cues a positive validity effect is also observed at short SOAs. However, positive validity effect in this condition endures for SOAs longer than 300 ms, but decrease greatly at SOAs longer than 500 ms (Posner *et al*., 1982). This suggests that for peripheral predictive cues there would be the involvement of an exogenous orienting process at early stages which allows a fast response to cued target, and an endogenous attentional process at late stages which allows the maintenance of attention at cued location even for longer SOAs (Chica *et al*, 2014). In summary, when a salient stimulus appears in the periphery of the visual field it automatically or reflexively (tens of milliseconds) captures attention to that location regardless of whether that stimulus carries any information relevant to the task. In contrast, a symbolic cue (e.g., a geometric figure) engages voluntary, top-down orienting of attention only when it is informative (predictive condition) about the target location, requires effort and takes longer times (hundreds of milliseconds).

Interestingly though, evidence have been reported demonstrating that fast and effortless orienting (related to automatic processes) may also occur when symbolic non-predictive cues are used (e.g., Friesen & Kingstone, 1998; Ristic *et al.*, 2002; Tipples, 2002; Ristic & Kingstone, 2012). These studies revealed that symbolic non-predictive cues, like representations of eye-gaze and arrows, induce validity effects even at SOAs as short as 100 ms. Similar results have been reported when using small numbers (1 or 2) as cues indicating the impending target in the left and bigger numbers (8 or 9) indicating the impending target in the right (Fisher *et al.*, 2003). One well accepted interpretation of these effects is that some symbols are repeatedly associated with a spatial location throughout an individual's life rendering, after a long repetitive training, an automatic orienting of attention particularly for overlearned spatial symbols (Fisher *et al*., 2003; Dodd & Wilson, 2009). In addition, Ristic & Kingstone (2012) suggest that there would be a third form of orienting of attention that would be neither exogenous nor endogenous, but would be an "involuntary attentional response that became automated after repeated exposure to environmental contingencies" (p. 256). In these cases, instead of "automatic" orienting, the term "automatized" orienting of attention will be used, in order to distinguish this kind of endogenous (automatized) orienting from exogenous, automatic orienting, thus emphasizing the learned nature of these associations by repetitive training.

In this context, it seems reasonable to speculate about what would be the amount of training for an initially directionally neutral symbolic cue to induce endogenous automatic orienting of attention when repeatedly associated with a spatial location. Dodd & Wilson (2009) and Guzzon *et al.* (2010) explored this question by associating initially neutral cues, e.g., textures and colors, respectively, with a location in space. Before and after the training they tested performance of subjects on a cueing task using the same trained stimuli as cues. For Guzzon *et al.* (2010) study the training sessions consisted of 160 trials in each day, 5 consecutive days per week, along 3 weeks. They used a predictive task (80% of valid trials) condition with four different SOAs (50, 100, 150 and 200 ms) for pre and post-test. It is important to note that the pre-test consisted of 552 trials which could already be accounted as training for cue-target association. A small validity effect was observed at the SOA of 200 ms for the pre-test. In contrast, for the post-test, larger validity effects were present not only at the SOA of of 200 ms, but also at a smaller SOA of 150 ms which did not show validity effect for pre-test. These results show that training improved the ability to orient attention by texture cues with no initial directional meaning. Furthermore, Dodd & Wilson (2009) showed results from an elegant study where pre and post-tests used non-predictive cues instead of predictive cues which eliminate the interference of a possible training from pre-test session. The training session consisted of 800 trials in one experiment and 1200 trial in another, where two colour cues where associated with a target location in 100% of trials. They observed that, after training with 800 trials, even with a non-predictive condition there was a small but significant validity effect at 100, 500 and 800 ms SOAs. After 1200 trials at training session, the validity effect at the same SOAs were larger than the ones observed with 800 training trials.. Together, these results indicate that repeated associations of initial non-directional symbolic cues and spatial locations can induce attentional effects similar to exogenous orienting with validity effect at short SOA (100 ms) for non-predictive cues, but also similar to endogenous orienting with no IOR at long SOA (800 ms).

Olk *et al.* (2014) investigated the occurrence of validity effects by using different types of symbolic cues including arrows, numbers and colors, with, respectively, strong, intermediate and weak spatial biases according to cultural contingencies. For instance, while arrows are culturally directional, therefore should produce automatized orienting of attention towards the indicated location, colors are not thus depending on the associations built along task performance. There were two conditions using numbers as cues. In the first condition the numbers 1 and 2 were used as symbolic cues to directed attention to left and right, respectively. Thus, the left location was associated with a smaller number and the right location was associated with the bigger number. In the second condition, the numbers 9 and 3 were used to directed attention to the left and right, respectively. Thus, the left location was associated with the number 9 and the right location with the number 3, because these are their locations in a clock watch. These cues were presented at SOAs of 100, 450 and 800 ms from the target. Even though all cues produced validity effects at all SOAs, larger cueing effects on reaction times and accuracy were observed when using arrow cues in comparison to numbers and colors. However, there was a slower and worse performance when using the numbers 9 and 3, as compared to colors and numbers 1 and 2. Another hypothesis they investigated was if there was a correlation with the size of cueing effects and speed of direction judgement for each type of cue. No correlations were found indicating that a fast speed to decode the direction of a cue is not associated with a larger cueing effect. Therefore, the reflexive-like orienting effects observed for overlearned spatial cues like arrows would not be related to the efficiency of processing the cue itself.

In addition to these findings interesting studies presented a different approach to the issue involving a voluntary aspect of endogenous orienting of attention using symbolic cues. In order to evaluate the involvement of volition in endogenous orienting of attention, Taylor *et al.* (2008) instructed subjects to choose where to attend, in addition to submitting them to a classical cueing task. The authors then analyzed fMRI data to compare brain activity when the subjects had to choose where to attend to after a given cue and when they attended following symbolic orienting (instructional) cues. The results revealed distinct underlying networks in free choice orienting of attention as compared to instructional orienting. While free choice orienting of attention involved medial frontal areas including pre-supplementary eye field (pre-SEF) and anterior cingulate cortex (ACC), orienting of attention by instructional cues activated dorsal fronto-parietal areas including the frontal eye field (FEF). Bengson *et al.* (2015) investigated brain activity by using combined EEG and fMRI in order to compare brain activity during choice and instructional cues in a cueing task. Similarly to Taylor *et al*. (2008), they observed activation of the ACC and SEF associated with choice cues but indicating a unique activation of regions only for choice cues compared to instructional cues which comprises the middle frontal gyrus (MFG), anterior cingulate (ACC) and anterior insula (AI). Apparently, a cognitive function related to AI activity would involve categorization of cue as endogenously relevant so a decisional process could occur for execution of deployment of attention related to the dorsal attentional system. Further, MFG appears to be involved with working memory, and its activity is related to decision-making tasks and conflict detection, which seems to agree with the need to choose between sides. The EEG results revealed two components related to what the authors called willed attentional control which they point out are components that reflect a group of cognitive operations involved with this type of control including stimulus categorization, conflict perception and willful decision-making. Results from these studies indicate that distinct neural networks are activated when different cognitive processes are required in order to orient attention endogenously. They also suggest that volitional (or willed) orienting of attention can be distinguished from a voluntary/instructed orienting of attention by symbolic cues. However, this distinction is not clear from behavioral results. Only Taylor *et al.* (2008) showed a difference of reaction time and accuracy between type of cues with choice cue related to a poorer performance when compared to instructional cues. Bengson *et al.* (2015) did not revealed any behavioral difference between the types of cues. Therefore it would be interesting to know if a behavioral distinction could be observed when using an appropriate task design to evaluate the time course of processes involved on each type of cue.

On considering the results of the studies reported above it seems unavoidable to think about how knowledge concerning endogenous orienting of attention was built relying mainly in a task that requires many trials and in which a symbolic cue and the relevant target are presented repetitively. In a classical cueing task with a predictive condition a cue is informative about the impending target location meaning that its presentation (and symbolic meaning) in valid trials is followed by presentation of the target at a single location as indicated repetitively by the cue. That is, there is a relevant relationship between cue and target that is repeatedly strengthened by associations along the task. Therefore, overlearned or over trained associations involving symbolic cue and target location could result in automatized orienting of attention, then rendering possible that orienting effects observed in a classical cueing task are actually related to endogenous automatic processes resulting from repeatedly cue-target associations than to actual voluntary (or volitional) processes. It is still unclear whether and how voluntary and automatized processes are involved in endogenous orienting of attention. For instance, what would be the effects of orienting of attention if facilitation from cue-target associations is avoided? What are the cognitive processes underlying voluntary control of orienting of attention? If choice cue involves distinct neural networks as compared to instructional cues, then there would be a temporal difference related to the processes involved in decision-making relative to where to attend to in each trial?

1.3. Neural mechanisms involved in orienting of attention

Behavioral studies have revealed basic principles of processes related to visual attention. Even though behavioral measures provide relevant information to understand the organization of perceptual and cognitive processes such as visual attention, experimental approaches to the underlying neural mechanisms involved in those processes are of great interest to give additional understanding to how the nervous system deals with visual information. Neuroimaging and neurophysiological studies have also investigated processes of attentional control and showed neural correlates for reflexive and voluntary processes of orienting of attention (Corbetta & Shulman, 2002; Mangun, 1995; Posner & Petersen, 2012).

Functional magnetic resonance imaging (fMRI) studies have shown the participation of distinct neural networks for voluntary (or top-down) and automatic (or stimulus-driven) control of attention (Corbetta *et al.*, 2000). Corbetta & Shulman (2002), in a review of the literature in this area, concluded that a dorsal frontoparietal network including the frontal eye fields (FEF) and the intraparietal sulcus exhibit sustained activity after an arrow cue indicates that attention should be oriented towards a relevant location for detection of an impending target. This sustained activity in anticipation to the impending target indicates that this network participates in voluntary orienting of attention, although it was elicited by arrow cues thus possibly involving an automatized process. In contrast, a ventral frontoparietal network seems to be more related to a reflexive orienting of attention. The temporoparietal junction (TPJ) cortex and the ventral frontal cortex (VFC) are activated when orienting occurs towards an unexpected sensory event, outside the location of preferential processing, and without a preparatory cue.

However, despite this distinction of networks for control of attention, there seems to be a general agreement that there is a relevant, but still unclear, interaction between them when orienting attention towards sensory stimuli. It seems that a highly predictive symbolic cue (100% valid), which is considered to involve a voluntary process, greatly influence the sensory salience of stimuli at a point of extinguishing the effect of abrupt onset, considered to trigger a reflexive orienting process, on performance of target detection (Yantis & Jonides, 1990; Folk *et al.*, 1992). These results indicate that a reflexive orienting process related to abrupt-onsets can be influenced by the subject's attentional control. If reflexive orienting is characterized by an insensitivity to concurrent perceptual load and not subject to voluntary control, then these results put into question what are the conditions for a purely a reflexive or exogenous orienting of attention to occur. Posner (2016) argue that distinct but interacting brain systems for voluntary and reflexive control of orienting of attention allows investigation of the neural basis for volition.

Attention and working memory seem closely related processes since they both can induce top-down biases in visual cortex in the absence of sensory stimuli (Kastner & Ungerleider, 2000). Furthermore, in spatial cueing tasks, after a cue is presented, the information about the spatial location about where to attend to needs to be maintained in working memory for the task to be performed properly. Neuroimaging evidence indicates that distinctive areas in the frontal cortex are activated when the subject is performing a working memory task for objects relative to spatial location (Smith & Jonides, 1999). The superior frontal sulcus exhibits activation during performance of a spatial working memory task (Courtney *et al.*, 1998). This area is close to those activated in visuospatial attention tasks, like the FEF and the SEF. Kastner & Ungerleider (2000) reported extensive activations of the FEF and the SEF during performance of visuospatial attention tasks which could mean that areas actually involved in spatial working memory would not be distinct from those involved with attention, and thus activity related to attention and working memory would derive from partially overlapping areas in the frontal cortex.

In the late 1960s, electroencephalography (EEG) began to be used to provide measures of human brain activity that could be related to behavioral performance, for the study of perception and cognition. Numerous physiological studies of selective attention have been done in the past 40 years using this approach, especially in visual-spatial attention, revealing complex time course of neural activity related to voluntary (Van Voorhis & Hillyard, 1977; Mangun & Hillyard, 1991; Eimer, 1994; Mangun, 1995) and automatic (Hopfinger & Mangun, 1998) attentional orienting. The high temporal resolution of EEG allows recording of brain activity “millisecond-by-millisecond”, and signal processing of the EEG to extract event-related potentials (ERP) to specific stimulus/task categories, thus providing a powerful tool for studying the dynamic brain processes involved in perception and cognition in humans (Eimer, 2014; Luck, 2014).

ERP studies of visual selective attention revealed that when a target stimulus was presented at attended location (compared to when presented in unattended location) it evokes an increased amplitude in a series of visual ERPs recorded from electrodes on the scalp. This includes a positive component (P1) after approximately 80 ms of the target onset, followed by modulation of a negative component (N1) at about 120 ms after target, as well as additional longer-latency components (Van Voorhis & Hillyard, 1977; Mangun & Hillyard, 1987; Mangun & Hillyard, 1991; Eimer, 1994; Mangun, 1995). Because the earliest of these ERPs are sensory-evoked responses, their amplitude modulation by attention is considered to reflect the activation of sensory gain control mechanisms during orienting of attention towards likely target locations, which results in enhanced processing of the attended events and improved behavioral performance (Mangun, 1995; Eimer, 2014).

ERPs studies have also investigated the mechanisms and time course of engagement of brain systems involved in the top-down voluntary orienting of attention; the so-called "attentional control mechanisms". In such studies, ERPs are recorded after the presentation of a symbolic cue but before the onset of the subsequent target stimulus (i.e., during the cue-to-target period). ERP components recorded from scalp sites contralateral to the location of the attentional shift were consistently observed in different experiments (Harter *et al.*, 1989; Nobre *et al.*, 2000; Hopf & Mangun, 2000). An early negative component, named Early Directing Attention Negativity (EDAN), was observed at posterior electrodes around 200 ms after cue onset (Harter *et al.*, 1989). It is hypothesized that this component would reflect initiation of voluntary shifts of visual attention (Hopf & Mangun, 2000). However, this relation has been challenged by the idea that this component could be a lateralized sensory response to an asymmetrical cue, like an arrow (Van Velzen & Eimer, 2003). Together, late ERPs components observed after cue onset were also related to covert attentional control. A negative deflection, known as Anterior Directing Attention Negativity (ADAN), observed at anterior electrodes around 300 ms after cue onset, has been related to activation of frontal control processes involved in initiating shifts of attention (Nobre *et al.*, 2000). Finally, at occipital scalp electrodes, late positivity, named Late Directing Attention Positivity (LDAP), appears around 500 ms post-cue. The LDAP component is regarded as signs of preparatory activity in visual cortex (under top-down control) that will be involved in processing the visual targets, thus leading to attention-related enhancements of the upcoming target stimuli (Harter *et al.*, 1989; Hopf & Mangun, 2000).

Other studies have shown distinct ERPs when investigating voluntary orienting of attention. For instance, Woodman *et al.* (2009) did not found EDAN, ADAN or LDAP components after cue presentation. However, they used a visual search array with the cued target among distractors different from studies mentioned above. They found a lateralized negativity 200 ms before target presentation which was interpreted as a N2pc-like (N2-posterior-contralateral) component because of its latency range and scalp distribution. This N2pc-like component would be related to an anticipatory selection of target and suppression of distractors. Also, they argue that this contralateral negativity could have masked the LDAP component (contralateral positivity) due to the same distribution that they have.

Brignani *et al.* (2009) investigated eventual differences in ERP components when endogenous orienting of attention was triggered by different types of cues. They used overlearned symbolic cues like arrows and eye-gaze figures, and a neutral symbolic cue like textures to cue a target location. They aimed at investigating the topography and amplitude of components like P1, N1, P2 (a positive component at around 200 ms after stimulus presentation), and P3 (a positive component at around 300 ms), and also the EDAN component. In short, results showed differences in latency of P3, which is related to discrimination, categorization and decision making processes, between cues with a longer latency for texture cues indicating that it required more cognitive resources for its processing than the other cues. Results related to EDAN seems to corroborate the hypothesis that this component is more involved with relevant features of cue stimulus rather than attentional orienting as mentioned above.

It is possible that distinct ERP results related to endogenous orienting of attention are due to the difficulty in comparing ERP components. Signal-averaging procedures used to isolate ERP components from EEG signal is a consistent way to observe a typified waveform related to an event. However, components mentioned here are considered small meaning that it is required a large number of trials (100 to 500) to observe reliable differences between groups or conditions (Luck, 2014). Furthermore, even though the paradigm used is very similar, slight task feature modifications like cues, targets or temporal course could affect observed ERP components. Even so, the combination of behavioral and electrophysiological studies seems to bring advantages when investigating control of orienting of attention and underlying neural mechanisms, especially because of the millisecond-temporal resolution of EEG recordings. This allows comparison of fast cognitive processes like automatic and voluntary processes involved in orienting of attention.

2. Objective

The main purpose of this study was to investigate if there are distinctions between voluntary and automatized processes involved in endogenous orienting of attention. Three experiments were conducted in order to investigate the orienting of attention time course when involving a “truly voluntary” process in comparison to an automatized process.

The first experiment, involving a variant of the classical cueing task, was an attempt to avoid repetitive association between the symbolic cue and target location, using SOAs at 150, 300, 700 and 1000 ms, and thus evaluate endogenous orienting of attention when an automatized process of orienting of attention is avoided.

In the second experiment, a behavioral and electrophysiological study involving ERP components was conducted in order to investigate the neural mechanisms underlying a voluntary process of attentional control by using a variant of the classical cueing task that consisted of changing the symbolic cue in a trial-by-trial basis. This way it was expected that orienting attention by a novel cue on each trial could render behavioral and electrophysiological effects related to a more voluntary process.

The specific goals were (1) to investigate the temporal course of behavioral effects when orienting of attention is triggered by automatized or voluntary processes, and (2) investigate if classical ERPs components correlate with a truly voluntary endogenous orienting of attention.

The third experiment involved a temporal order judgement task combined with spatial cueing to investigate stimulus order perception when attention is oriented to a location by different types of cues including arrows, symbolic cues associated with a spatial location, and a choice cue that requires that the subject freely choose where to attend, that would involve automatized, or voluntary, or volitional orienting processes.

3. Chapter I

Are there voluntary and automatized processes involved in endogenous orienting of attention?

In this first study two experiments were conducted in order to investigate to which extent endogenous orienting of attention includes two dissociable underlying processes, one voluntary and the other automatized by repeated cue-target location pairings. For this, a variant of the classical cueing task was designed, and consisted of inserting a stimulus between cue and target which had to be reported or not by different groups. This stimulus, called anchor, when required to be reported was expected to function as a temporal signal to when orient attention. Therefore repetitive presentation of predictive symbolic cue and target at a specific location could be avoided or weakened when report of anchor was required. With that in mind it was possible to investigate whether anchor report or no-report would result in different cueing effects when evaluating time course of orienting of attention. The hypothesis was that by avoiding repetitive cue-target contiguous presentation, the process involved in endogenous orienting of attention would be more controlled, or voluntary, and orienting would take more time rendering cueing effects only at long time intervals between cue and target. In contrast, if not required to report anchor, cue-target association would be reinforced and the process involved in orienting attention could become automatized rendering cueing effects in short time intervals between cue and target as well as in long time intervals.

Are there voluntary and automatized processes involved in endogenous orienting of attention?

Jordão, E.M.A.[1]* and **Xavier, G.F.**[1]

[1] Department of Physiology, Institute of Biosciences, University of São Paulo, São Paulo, Brazil
*Corresponding authors: elisa.jordao@usp.br and gfxavier@usp.br.

Abstract

Key-words: visuo-spatial attention; endogenous orienting of attention; voluntary; automatized

This study investigated to which extent endogenous orienting of attention includes two dissociable underlying processes, one voluntary and the other automatized by repeated cue-target location pairings. The temporal course and effects of interfering with the repetitive contiguous presentation of cue and target, in a variant of the classical spatial cueing task, was investigated in two experiments. For that, a stimulus, named anchor, inserted between the cue and the target was required to be reported or not for different groups. If anchor had to be reported then it would function as a temporal signal to when orienting attention should occur. In the first experiment, four groups performed the variant of the cueing task of which two groups had to report anchor and two groups did not. The groups also varied in predictive and non-predictive condition of cue-target relationship. Four different time intervals between anchor and target, the stimulus-onset asynchrony (SOA), was used (150, 300, 700 and 1000 ms). Results showed that the group in a predictive condition that had to report anchor did not show cueing effects at the shortest SOA, but the group in a predictive condition that did not have to report anchor showed cueing effects at all SOAs. No cueing effects were observed for groups in a non-predictive condition. Results indicate that anchor report did interfere with orienting of attention particularly at a short time interval between anchor and target. The second experiment aimed at investigating whether anchor would function as a temporal signal for orienting attention even when not required to be reported. Two groups performed the variant of the classical cueing task both in a cue-target predictive condition. The group that had to report anchor was exposed to two different SOAs, 350 and 700 ms. As to the group that did not report anchor was exposed to two others SOAs, 100 and 450 ms. Because the time interval between cue onset and anchor onset was of 250 ms, these SOAs were comparable if considered that orienting of attention would start from cue presentation for groups that did not report anchor, and start from anchor presentation for groups that did report anchor. Cueing effects were observed at both SOAs for the group that reported anchor, but no cueing effects were observed at any SOAs for the groups that did not report anchor. These results indicate that anchor interfered with the orienting process even when not required to be reported, thus also functioning as a temporal signal even if not relevant to the task.

1. Introduction

Selective visual attention is the ability to prioritize processing of one or a few task-relevant items in a scene while also ignoring irrelevant or distracting stimuli. Attentional orienting is considered to take two main forms: one is automatic or reflexive orienting (termed exogenous orienting/attention) and the other is voluntary orienting (termed endogenous orienting/attention) (Posner, 1980). These two forms of attention are dissociable experimentally as each has its own characteristics (Posner & Cohen, 1984). The former would occur rapidly and without subject's control. The later would require the subject's control, and therefore would take place more slowly.

The classical experimental paradigm where this dissociation was observed are spatial cueing tasks. For reflexive attention, a salient stimulus (e.g., a briefly flashed stimulus) is presented somewhere (usually parafoveally or peripherally) in the visual field, and is followed by a task-relevant target stimulus, which may appear at the same location or another location. For voluntary attention, a cue (e.g., an arrow) is typically presented at the fixation point, and indicates to a peripheral location where an impending target may appear after an interval of time, or the target may also appear elsewhere. In this task, cues may be either valid or invalid in each trial. In invalid trials the cue misleads orienting of attention towards the opposite location relative to where the target appears. In valid trials the cue indicates the target location correctly (Jonides, 1981; Posner & Cohen, 1984). If, in a task, the majority of trials are valid than invalid then it is considered a predictive condition, i.e. the cue predicts where target will appear. In contrast, if the proportion of valid and invalid trials are the same then the cue does not predicts where the target will appear, and this condition is considered non-predictive. The different types of cues combined with cue-target conditions have been shown to engage different orienting processes; exogenous orienting with non-predictive peripheral cues, and endogenous with predictive symbolic cues (Chica *et al.*, 2014). These processes follow different time courses, which were revealed by examining the speed or accuracy of responses to targets as a function of the stimulus-onset-asynchrony (SOA) of cue and target which typically varies from 50 to 1000 ms (Jonides, 1981; Muller & Rabbitt, 1989). Put simply, when a salient stimulus appears in the visual field (peripheral cue) it automatically and rapidly (tens of milliseconds) attracts attention to that location in space regardless of whether that stimulus carries any information relevant to the task, being predictive or non-predictive. In contrast, a symbolic cue (e.g., an arrow), engages a voluntary, endogenous, top-down orienting of attention that requires effort and takes more time (hundreds of milliseconds) only when they are predictive. In addition, the rapid onset of facilitation for peripheral cues is accompanied by a quick decline in facilitation, which may even be replaced by inhibition, known as “inhibition of return” (Posner & Cohen, 1984; Klein, 1988; Tassinari *et al.*, 1994).

There have been reports that symbolic cues, typically associated with endogenous orienting, may induce an automatic-like orienting of attention regarded here as an automatized process (Friesen & Kingstone, 1998; Driver *et al.*, 1999; Ristic *et al.*, 2002; Tipples, 2002; Olk *et al.*, 2014). These cues include arrows, simple figures representing gazing direction, and symbols presented close to the fixation point repetitively paired with presentation of the target in a specific spatial location.Several studies have shown automatized orienting of attention when using these symbolic stimuli and suggest that it is related to an overlearned association between these cues and the spatial location they indicate. These cues are considered to promote automatized orienting because validity effect (i.e. reaction time difference between invalid trials and valid trials) was observed even in the non-predictive condition (Tipples, 2002), and at SOAs as short as 100 ms (Ristic *et al*., 2012, Olk *et al.*, 2014) usually associated with exogenous orienting of attention. Therefore, it seems that these cues promote orienting of attention very rapidly and without being predictive.(Ristic & Kingstone, 2012).

Furthermore, it is possible to develop associations between completely arbitrary visual stimuli and locations in space, thus producing similar attentional effects as those seen with arrows and eye-gaze images. Dodd & Wilson (2009) tested performance of participants on a non-predictive cueing task before and after a training session. This session consisted of 800 or 1200 trials, in different experiments, where colour cues were presented before a target presentation at specific locations 100% of the time. They observed cueing effects at 100 ms SOA after the training session, but not before, even with a non-predictive cue condition, and the effects were larger after the longer training. Guzzon *et al.* (2010) did a daily training for 15 days over three weeks associating textures to a target presentation at a specific location. They observed cueing effects at SOA as short as 150 ms when orienting attention by predictive texture cues after the training that was not observed before the training. These results support the idea that a reinforced association between cue and target could evoke an automatized orienting of attention similar to the one involved with gaze and arrow cues.

These evidence instigate questions about whether in a classical cueing task which may involve more than 800 trials, reinforcement of associations between symbolic cues and the target location in a predictive condition (i.e. majority of valid trials) could lead to an automatized process of endogenous orienting of attention. If this is true then it should be possible to distinguish automatized from voluntary processes by reducing the possibility of associations between cue and target location along repetitive training.

In order to further investigate the involvement of these processes in endogenous orienting of attention, a variant of the classical cueing task was developed. Differently from other studies mentioned here, this study aimed at focusing on voluntary process of endogenous orienting of attention in contrast to a possible automatized process built on cue-target associations. The task was designed with the purpose of avoiding or lessening, and not by strengthening, these associations.

The task consisted of inserting a visual stimulus at the fixation point, called anchor, between presentation of the cue and the target. The anchor was composed of combinations of 2, 4 or 6 circles that was randomly presented along trials. For a group of subjects the number of circles composing the anchor had to be reported at the end of each trial. The requirement for reporting the anchor aimed at stimulating the participants to maintain their attention focused at the fixation point until anchor onset, thus minimizing the association between the cue and the target. For the other group this was not required. Therefore, when report was required, the anchor was intended to temporarily segregate cue and target thus minimizing their association, particularly when the subjects had to report it. In contrast, when report of the anchor was not required, it could be ignored thus facilitating the cue-target association.Two experiments here reported were conducted using this task in order to understand the temporal course of endogenous orienting of attention when anchor was reported in comparison to when it was not.

2. Experiment IA

In this experiment the temporal course of endogenous orienting of attention was investigated either with or without report about the anchor. Supposedly, when the subjects report the anchor the possibilities for cue-target associations are minimized. Four groups of subjects were organized according to the treatment, including anchor report (either report or no-report) and cue-target predictiveness (either predictive or non-predictive). The cues for each subject could be either valid (64% or 44%) or invalid (20% or 44%) for predictive or non-predictive cue conditions, respectively. Four different SOAs were used for all groups, short SOAs (150 ms and 300 ms) and long SOAs (700 ms and 1000 ms). Validity effects were expected at longer SOAs for subjects that had to report the anchor, particularly for subjects in the non-predictive cue-target condition. Because meaning of symbolic cue was informed beforehand and directing attention towards the target location would be voluntary, then RT for valid trials would be faster than those for invalid ones. It was also expected that validity effect would be observed in all SOAs for subjects with no requirement to report the anchor when cue was predictive, but lack of validity effect for subjects exposed to non-predictive cues. Because, in this last case, relationship between cue and target would not be reinforced during task given the lack of predictiveness of the condition.

2.1. Materials and method

2.1.1. Participants

Forty-one healthy volunteers, twenty-six women and fifteen men, average age of 22.6, participated in the study. Thirty-eight participants were right-handed and three left-handed according to an adapted Edinburgh Handedness questionnaire. One man was excluded due to excessive errors (>30%). All participants had normal or corrected-to-normal vision and no history of neurological disorders. They all read and signed a consent form. Participants were organized into four groups determined by either requirement of report about the anchor or no report, and by predictiveness of the cue. The groups were as it follows: 1) Anchor Report - Predictive cue (AR-P, N=10); 2) Anchor Report - non-Predictive cue (AR-nP, N=10); 3) Anchor non-Report - Predictive cue (AnR-P, N=10); and 4) Anchor non-Report and non-Predictive cue (AnR-nP, N=10).

The protocols were approved by the University of São Paulo, Institute of Bioscience Human Research Ethics Committee (protocol number: 44577015.8.0000.5464).

2.1.2. Stimuli and procedure

Data were collected in a quiet room with a dim light. The subject seated in a comfortable chair and placed her/his head in a chin rest at 57 cm from a laptop screen (refresh rate of 60 Hz). They were required not to move their eyes during the trial; eyes movements were monitored by a night camera. All stimuli were white presented in a black background. At the beginning of the trial participants had to gaze at a centralized point and maintain it during the hole trial. Both cues were circles (0,3° radius) presented either above or below the fixation point (0,8° distance). Anchors were a set of two, four or six circles and had the same size and distance from fixation point as cues. Targets were circles (0,4° radius) presented to the right or to the left of fixation point (12° distance). For a trial example see a scheme in Figure 1. Reaction time was recorded using a mouse and report about the anchor involved a numerical keyboard. The task was programmed using Psychopy software (Peirce *et al.*, 2019).

2.1.3. The task

The task consisted of eight hundred trials divided in four blocks. All conditions were counterbalanced and presented pseudo-randomly. There were four different stimulus-onset asynchronies (SOAs) between the anchor and the target (150, 300, 700 e 1000 ms). There were valid trials, when cue indicated correctly the location of target (68% for predictive cues and 44% for non-predictive cues), and invalid trials, when cue indicated incorrectly the location of target (20% for predictive cues and 44% for non-predictive cues). Catch trials, when no target was presented, corresponded to 12% of trials for all groups). A trial began with the subject gazing at the fixation point. After 1000 ms, a cue was presented for 50 ms. Then, 250 ms after the cue presentation, the anchor was presented for 50 ms. Then, the SOA elapsed and the target was presented for 30 ms. Reaction times for response to the target were registered. Omission errors were recorded when the subject did not respond up to 1000 ms after the target presentation. Anticipation errors were recorded when the subject responded before either before the target presentation or 100 ms after its onset. Catch trials errors corresponded to the emission of a response without any target presentation. At the end of the trial a question about the number of circles composing the anchor was presented on the screen for the subjects included in the groups that had to report the anchor. The subjects responded using a numerical keyboard.

Median of reaction times for trials with correct responses were obtained for each condition. They were then subjected to repeated measures ANOVAs using boxcox transformed RT data including SOAs and Validity (either valid or invalid trial)as within subjects factors, and Group as between subjects factor. Post-hoc Tukey HSD tests were conducted when necessary. The percentage of each type of error was (i.e. anticipation, omission, catch trial) calculated as well as the percentage of correct reports for the anchor including the subjects that had to reported it. Analysis of errors and anchor report was conducted using a General Linear Model (GLM) after percentage was log transformed. GLM was used instead of ANOVA for its flexibility to deal with low variance of data. Analyses were conducted using R software packages.

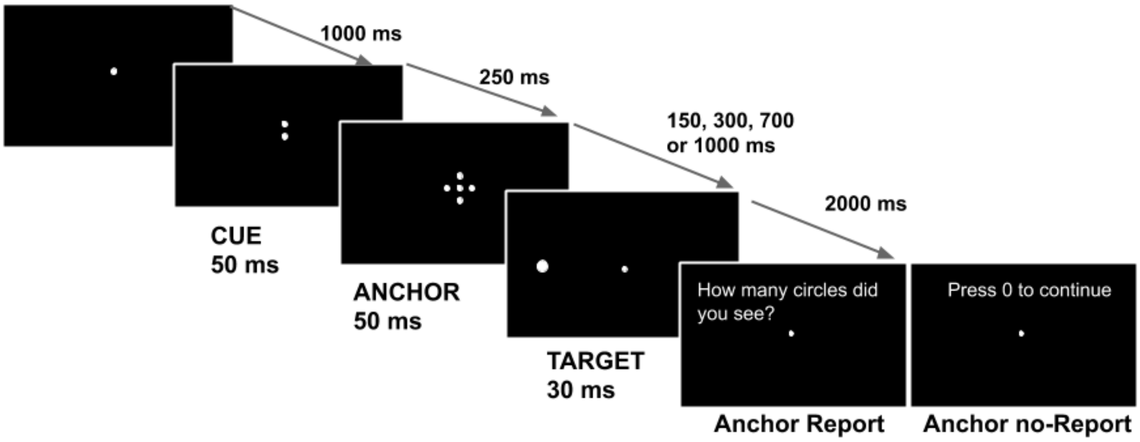

Figure1. Scheme representing a valid trial of the task in Experiment I. Stimuli are not in scale.

2.2. Results

2.2.1. Reaction time

Figure 2 shows reaction times (RT) as a function of Anchor report, Predictability, Validity and SOAs. ANOVA revealed a significant main SOA effect ($F_{3,102}=160.14$, $p<0.0001$, $\eta_p^2=0.169$) and a significant Group x SOA interaction effect ($F_{9,102}=8.42$, $p<0.0001$, $\eta_p^2=0.031$). A post-hoc Tukey's test indicated that subjects that did not have to report the anchor (AnR-P; AnR-nP) exhibited longer reaction times at the shortest SOA (150 ms) relative to their own reaction times at longer SOAs (300 ms, 700 ms, 1000 ms) ($p<0.05$). Differently, subjects that had to report the anchor (AR-P; AR-nP) exhibited much longer reaction times at SOAs of 150 and 300 ms relative to their own reaction times at SOAs of 700 and 1000 ms. Post-hoc test also showed that subjects of the AR-P group differed significantly from all other groups at shorter SOAs (150 ms and 300 ms) both groups that reported anchor, AR-P and AR-nP, differed significantly from groups that did not reported anchor. This effect of SOA in reaction times depending on group suggest that when anchor needs to be reported and, in addition, when cues are predictive then detection of target is delayed probably due to more processing demands.

A difference of mean RTs for valid versus invalid trial condition (validity) appears to occur for groups with predictive cues condition. ANOVA shows that there is a Validity main effect ($F_{1,34}=35.7$, $p<0.0001$, $\eta_p^2=0.015$) and a significant Group x Validity interaction effect ($F_{3,34}=9.4$, $p<0.0001$, $\eta_p^2=0.012$) supporting the difference observed in the descriptive data. Post-hoc Tukey's test indicated a validity effect for both groups with predictive cues (AR-P and AnR-P) indicating that the predictive cue condition was necessary for validity effect to occur. No interaction effect was found between SOA and validity, despite a perceptible lack of validity effect for the shortest SOA (150 ms) in AR-P group. Furthermore, analysis did not indicated a significant main effect of Group ($F_{3,34}$=0.78, p=0.52, η_p^2 =0.087), no interaction effect of SOA and Validity (p=0.37) or Group, SOA and Validity (p=0.2).

To better evaluate the data, another analysis was conducted using the same data but including SOA and Validity as within-subject factors, and Anchor report (report, no-report) and Predictability (predictive cue, non-predictive cue) as between-subject factors. This way it was possible to assess the effects of these factors separately rather combined into groups. Repeated measures ANOVA revealed the similar effects as previous analysis and other relevant interaction effects. Main effects of SOA ($F_{3,102}$=160.14, p<0.0001, η_p^2 =0.169) and Validity ($F_{1,34}$=35.7, p<0.0001, η_p^2 =0.015) was also observed, but no significant main effects of Anchor report ($F_{1,34}$=2.07, p=0.16, η_p^2 =0.08) or Predictability ($F_{1,34}$=0.063, p=0.804, η_p^2 =0.003). Interaction effects were revealed for Anchor report x Predictability x SOA ($F_{3,102}$=9.79, p<0.0001, η_p^2 =0.012) indicating that effects of longer SOAs interacted with task's demand for reporting the anchor and to use the cue to guide attention. No interaction effect also observed for Anchor report and Validity ($F_{1,34}$=0.914, p=0.34, η_p^2 =0.00), but it was revealed an interaction effect between Predictability x Validity ($F_{1,34}$=27.2, p<0.0001, η_p^2 =0.011) which was not surprising given the results of previous analysis. However, this analysis did reveal significant interaction effect between all the factors Anchor report x Predictability x SOA x Validity ($F_{3,102}$=2.848, p=0.036, η_p^2 =0.004). Pos-hoc Tukey's test showed that there was an effect of validity for predictive cue factor independently of anchor report for all SOAs except for the shortest SOA (150 ms) at which validity effect was significant for predictive cue with anchor no-report (p<0.001) but was not significant for predictive cue with anchor report (p=0.92). Therefore, this analysis corroborate the lack of validity effect only at the shortest SOA for the predictive cue group that had to report anchor, and validity effect observed in all SOAs for the predictive cue group that did not have to report anchor.

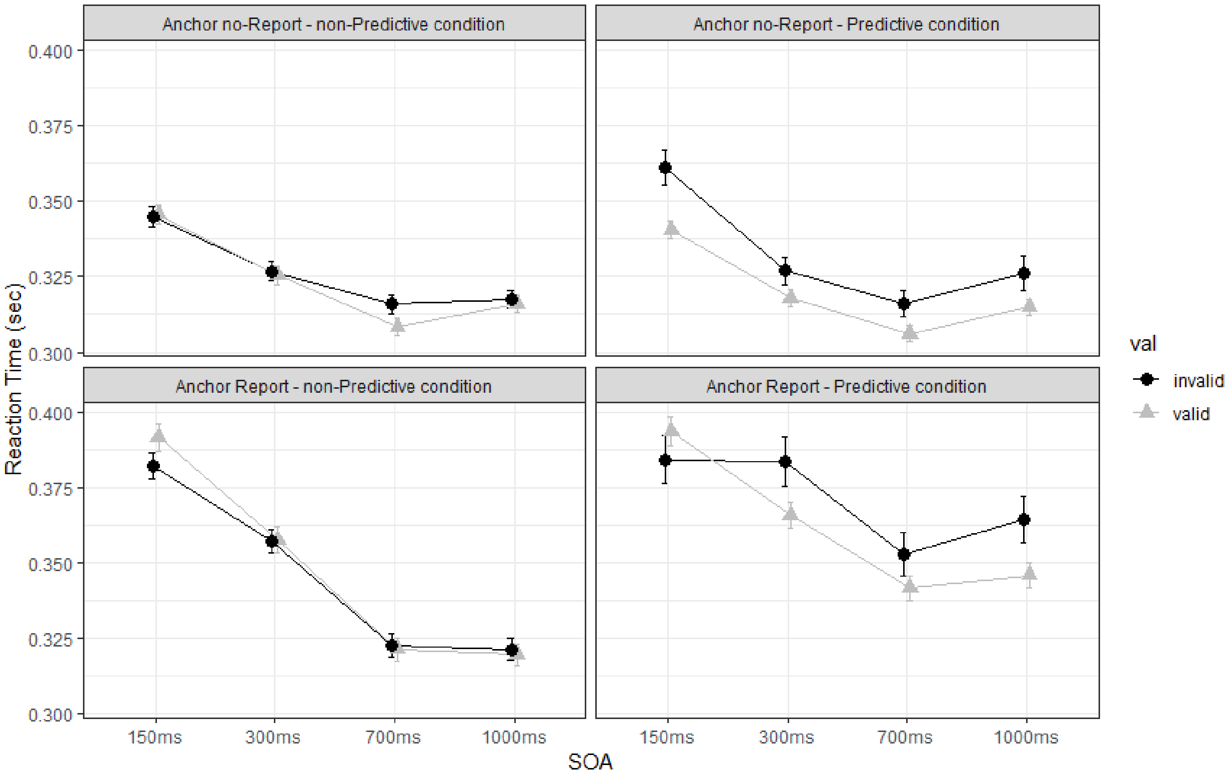

Figure 2. Mean (±s.e.m) reaction times for correct trials as a function of Anchor report (no-report = top panels and report = bottom panels), Predictability (non-predictive = left panels and predictive = right panels), cue Validity (valid and invalid) and SOAs.

Together, these results indicate the involvement of a voluntary process in endogenous orienting of attention, particularly for subjects AR-P, since validity effect in this group is consistent at longer SOAs (300 ms, 700 ms and 1000 ms) and was not observed at the shorter SOA (150 ms). In addition, higher RTs were observed in this group, for both valid and invalid trials, relative to AnR-R subjects, suggesting that the anchor report did slow down the response, either because it avoided cue and target location association and/or because it drained attentional resources from the cueing task. Furthermore, higher RTs at the longest SOA for AR-P subjects, as compared to AR-nP, subjects indicates that orienting of attention towards an invalid location substantially increase RTs when the subjects were trained in a Predictive condition.

2.2.2. Target response errors and anchor report accuracy

Figure 3 shows the percentage of anticipation (left panel), omission (middle panel) and catch trials (right panel) errors as a function of anchor report and predictability.

As reported above, anticipation errors included responses after the cue and before the target presentation or up to 100 ms after the target onset. A higher percentage of anticipation errors is seen for subjects that reported the anchor associated with the predictive condition (AR-P). The General Linear Model (GLM) for anticipation errors as a function of groups revealed lack of significant effect ($F_{3,34}=2.1$, $p=0.13$, $R^2=0.15$) of the overall model considering all effects together. However, individual effects analysis showed a significant difference between AR-P and AnR-P coefficients (-0.52, $p=0.035$). A close to significant difference between AR-P group and AnR-nP group was observed (-0.43, $p=0.07$). A negative slope denotes a decrease of percentage from AR-P to AnR-P and to AnR-nP. Difference between AR-P and AR-nP despite being also negative was not significant. This result shows that the subjects made more anticipation error when report of the anchor was required as compared to subjects that did not report the anchor in the predictive condition.

Catch trials were trials without target, and errors were considered when a response was given in these trials. Subjects that had to report the anchor exhibited a higher percentage of catch trial errors as compared to subjects that did not reported the anchor. The GLM analysis of catch trial error as a function of group was close to significance ($F_{3,34}=2.67$, $p=0.06$, $R^2=0.19$). Analysis comparing each group indicated that AR-P group differed significantly from AnR-nP (-0.84, $p=0.018$) indicating that AR-P group showed a higher percentage of catch trial compared to AnR-nP group. Therefore, subjects made less catch trial errors when they were not required to report anchor and when the condition was non-predictive.

Omission error consisted of lack of response up to 2000 ms after the target presentation. The subjects of AR-P group seem to omit responses more often than the subjects in other groups, howevere their variance was bigger perhaps due to one specific subject that made 19% of omission errors. With the exception of this subject, less than 9% of this type of error was seen for the other subjects. GLM analysis of omission error as function of group did not revealed significance of overall model ($F_{3,34}=1.95$, $p=0.13$, $R^2=0.14$). However, comparisons between groups revealed a significant difference between AR-P group and AnR-P group (-0.65, $p=0.04$), and a close to significant difference between AR-P group and AnR-nP group (-0.58, $p=0.06$). Thus, this analysis indicates that AR-P group does indeed exhibit more omission errors as compared to AnR-P and AnR-nP, but not AR-nP.

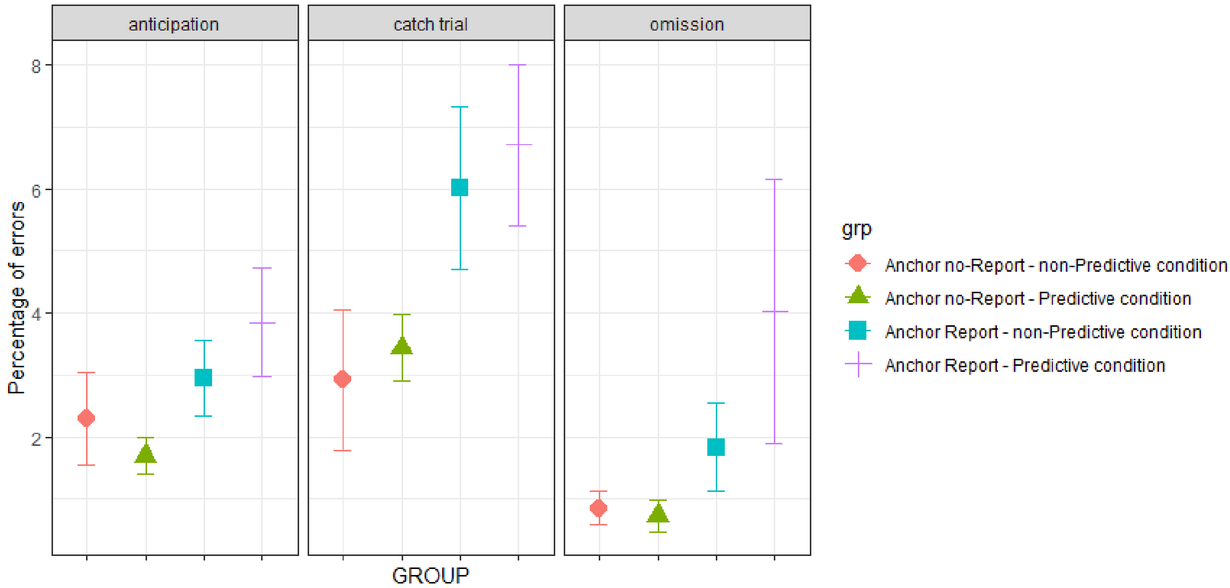

Figure 3. Mean (±s.e.m) of the percentage of errors (anticipation, catch trial and omission from left to right panels) as a function of group (AnR-nP, AnR-P, AR-nP and AR-P).

Accuracy about the anchor report was greater than 93% for both groups independently of validity, anchor report and SOA. GLM analysis of accuracy considering Group, SOA and Validity to fit the model showed a lack of significant effects of these variables in accuracy. This high accuracy and lack of effect indicate that the subjects did dedicate to detecting, identifying and reporting the anchor. It could be argued that reporting the anchor is not a difficult task. Even if this is the case, the groups required to report it exhibited changes in reaction times, thus indicating that it interfered with performance of the cueing task.

2.3. Discussion

Results clearly shows that predictive cue condition is necessary for orienting of attention to occur. The process involved in orienting of attention seems to be slower when anchor is required to be reported since no validity effect was observed for the shortest SOA (150 ms) for AR-P group, and significant validity effects at all SOAs for AnR-P group was revealed. Another evidence of a slower orienting of attention process for AR-P group was higher RTs, even in longer SOAs, compared to the other groups. Furthermore, a tendency for higher percentage of errors was also observed for AR-P group indicating that attending to anchor and then orienting attention to cued location decreased performance for target detection. Therefore, it seems that the process of reporting anchor interfered with overall performance of the task which indicates that orienting of attention in this condition requires a more controlled or voluntary process.

However the time course of the processes involved in the task were still uncertain. How anchor stimulus interfered with orienting of attention for groups that did not have to report anchor? It could be argued that validity effect observed for AnR-P group was due to a longer time interval between cue onset and target presentation since anchor could be ignored. That is, if orienting of attention occurs before anchor presentation for the AnR groups then time available for orienting process to occur was much longer in comparison to the time available for AR groups. Therefore comparing all groups with the same time interval between anchor and target (i.e. SOA) could be a confound. Therefore, Experiment IB was conducted using the same task reported here in order to investigate the effects of endogenous orienting of attention for two groups that did or did not have to report anchor and with different time intervals between anchor and target.

3. Experiment IB

In Experiment IA it was observed a cueing effects for groups with a predictive cue condition, specially within the group that did not have to make an anchor report. For this group a cueing effect was observed at all SOAs even at the shortest one (150 ms). However, these results raised a question related to the moment that orienting occurs when requirements for anchor report are distinct. If participants do not need to report anchor, do they orient their attention right after presentation of the cue? Or does the anchor, even if instructed to be ignored, influence the moment at which orienting of attention starts to occur? If orienting occurs from presentation of cue then the group with no-report of anchor (AnR-P) had a significant longer time to orient attention because time intervals between the cue, anchor and target was the same for all groups. Therefore, this experiment was conducted in order to investigate whether the anchor stimulus interfere with orienting of attention even when not required to be reported. For this, similar to Experiment IA, behavioral effects were compared between two groups, one required to report anchor and the other with no-report of anchor required, but both in a predictive cue condition. The difference between the first experiment was that, in this study, the time interval between anchor and target presentation, considered the stimulus-onset asynchrony (SOA), differed between the two groups. The anchor report group (AR) was tested for 350 and 700 ms SOAs, and the anchor no-report group (AnR) was tested for 100 and 450 ms SOAs. These SOAs were used because for AnR group 100 ms would be very short to orient attention, but 350 ms would not. Therefore, if AnR group actually oriented attention from cue-onset then subjects would have enough time to orient attention at 100 ms SOA and validity effect would be observed at both SOAs. However, if AnR group also oriented attention from anchor, as would be the case for AR group, then validity effect would be smaller or nonexistent at 100 ms SOA, but not at 450 ms SOA. The SOAs used for AR group were calculated so the time intervals for orienting attention would be the same for each group if considered that orienting of attention starts from cue-onset for the AnR group (with 350 and 700 ms cue-target intervals), and orienting of attention starts from anchor-onset for the AR group (with 350 and 700 ms anchor-target intervals).

3.1. Materials and method

3.1.1. Participants

Eighteen healthy volunteers, thirteen women and five men, average age of 28, participated in the study. Sixteen participants were right-handed and two left-handed according to an adapted Edinburgh Handedness questionnaire. All participants had normal or corrected-to-normal vision and no history of neurological disorders. They all read and signed a consent form. Participants were pseudo-randomly divided into two groups determined by conditions to report or not the anchor presented between cue and target presentation. Two participants all women and right-handed were excluded due to excessive errors (>30%). Thus groups were divided into: 1) Anchor Report (AR, N=8) and 2) Anchor no-Report (AnR, N=8). The study was approved by the University of São Paulo, Institute of Bioscience Human Research Ethics Committee (protocol number: 44577015.8.0000.5464).

3.1.2. Stimuli and procedure

Data were collected under the same conditions as Experiment IA with the exception of the computer and screen used (LCD with refresh rate of 240 Hz). All stimuli and procedure were the same as described above.

3.1.3. The task

The task consisted of 432 trials divided into four blocks. All conditions were counterbalanced and presented pseudo-randomly. Each group used two different stimuli-onset asynchrony (SOA) between anchor and target presentation, 100 ms and 450 ms for AnR group, and 350 ms and 700 ms for AR group. Catch trials (no target) consisted of 10% of all trials. Cues indicated correctly the target location in 70% of trials, or indicated incorrectly the location of target in 20% of trials. Trial began with a fixation point, after 1000 ms cue was presented for 50 ms. Anchor was presented for 50 ms after 250 ms of cue presentation, and after one of the two SOA the target was presented for 30 ms (see Figure 4 for a scheme of the task). After responding to target using a mouse, a question about the quantity of circles that composed anchor was asked to participants in AR group after each trial. Reaction time and errors were recorded and computed the same way as in Experiment IA. The same statistical analysis used in Experiment IA was also employed in this study.

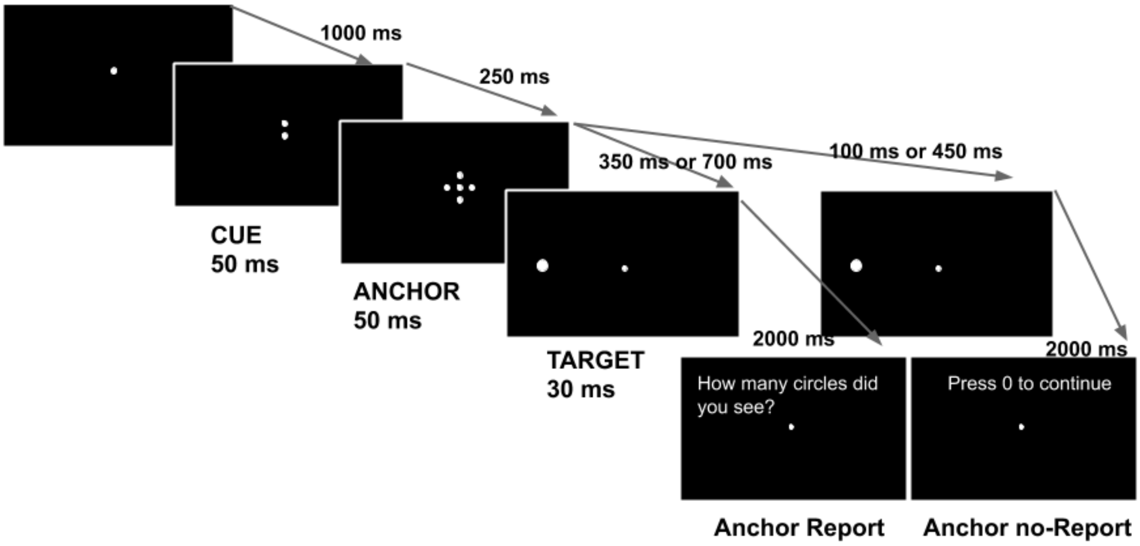

Figure 4. Scheme representing a valid trial of the task in Experiment II for both groups. Stimuli are not in scale.

3.2. Results

3.2.1. Reaction time

The descriptive data of RTs are observed in Figure 5 as a function of groups (AnR and AR), SOAs (100 and 450 ms for AnR, and 350 and 700 ms for AR) and validity of cue condition (valid and invalid).

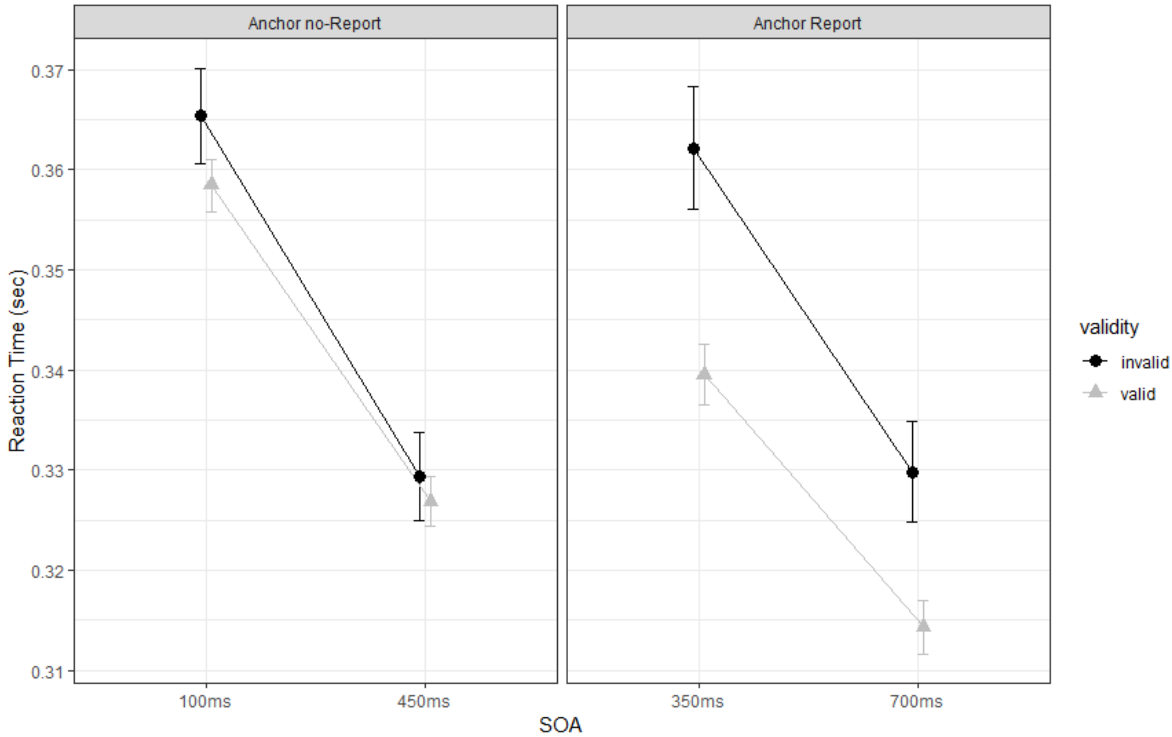

Figure 5. Mean (±s.e.m) of reaction time considering the two groups (AR and AnR), SOAs (100 and 450 ms, and 350 and 700 ms, respectively), and validity of cue condition (valid or invalid).

A lack of validity effect seems to occur for AnR group at short SOA (100 ms) and long SOA (450 ms). In contrast, a large validity effect is observed for AR group at both SOAs. Repeated measures analysis of variance (ANOVA) for SOA and Validity as within-subject factors, and Group as between-subject factor showed no significant main effect of Group ($F1,17=0.75$; $p=0.38$, $\eta_p^2=0.034$). However, it was observed a main effect of SOA ($F1,17=109.97$; $p<0.0001$; $\eta_p^2=0.073$) indicating a significant decrease of RTs with increase of SOA, and a main effect of Validity ($F1,17=11.2$; $p<0.001$; $\eta_p^2=0.005$) suggesting that RTs differed significantly when target was correctly cued in comparison to incorrectly cued target. Furthermore, it was also showed a significant interaction effect of Group x Validity ($F1,17=3.9$; $p=0.047$; $\eta_p^2=0.004$) indicating that the main validity effect was related to valid and invalid cue differences in AR group. Post-hoc Tukey's test showed that only AR group had an significant effect of validity ($p<0.001$) in comparison to AnR group ($p=0.34$).

3.2.2. Target response errors and anchor report accuracy

Anticipation, omission and catch trial errors were registered as reported in Experiment IA. Less than 8%, 3% and 16% of each type of errors, respectively, was observed for all subjects. A general linear model (GLM) analysis of each type of error was conducted as function of group. No significant effect was found in the analysis for anticipation error (R^2=0.03, p=0.4), omission error (R^2=0, p=1), and catch trial error (R^2=0.0005, p=0.92). The comparison between groups showed that there was no significant difference between AR group and AnR group for anticipation error (-0.6076, p= 0.47), omission error (0.000, p=1), and catch trial error (-0.231, p=0.93).

Anchor report accuracy was higher than 97% for all subjects in AR group indicating that participants did attend to anchor and performed well, similarly to results found in Experiment IA.

3.3. Discussion

The results and analysis of this experiment suggest a significant interference of anchor stimulus presentation even if instructed to be ignored. The lack of validity effect for AnR shows that participants did not orient their attention to cued target location even with a longer SOA of 450 ms. A possible hypothesis for this lack of validity effect at long SOA could be because of difficulty in using the cue to orient attention since almost half of trials (around 215) on the task had a short SOA (100 ms) that did not allowed for orienting to occur. Therefore, strengthening the association between cue and target location could have been impared, and subjects were less motivated to use the cue to orient attention even with a longer time interval. This suggest that, even if instructed to be ignored, anchor does interfere with orienting attention perhaps by attracting attention to fixation point and causing the shift of attention to occur only after its presentation. Therefore, orienting effects from groups that did or did not have to report anchor could be compared when using the same SOAs. In this context, it is possible to interpret that, in Experiment I, the group that did not report anchor (AnR-P) had more trials (around 380) with longer SOAs (300, 700 and 1000 ms) to strengthen cue-target associations which would allow for subjects to use the predictive cues and orient attention properly at all SOAs, even at the shortest (150 ms).

4. General discussion

As mentioned before, studies show that endogenous orienting of attention could involve an automatized process rather than just a purely voluntary process (Friesen & Kingstone, 1998; Driver *et al.*, 1999; Ristic *et al.*, 2002; Tipples, 2002; Olk *et al.*, 2014). In a classical cueing task, symbolic cues like arrows or eye-gaze representations are considered to trigger automatized shifts of attention because of the overlearned association between the symbolic cue and a relevant location in space (Ristic & Kingstone, 2012). Furthermore, studies have shown that a similar effect of automatized endogenous orienting of attention is possible when strengthening the association of symbolic cues and a location in space from training during several days (Guzzon *et al.*, 2010) or hundreds of trials (Dodd & Wilson, 2009). Results from these studies showed that an automatized endogenous orienting of attention would render validity effects at SOAs as short as 100 ms even with non-predictive cues (Dodd & Wilson, 2009). In contrast, a voluntary endogenous orienting of attention would occur in time intervals longer than 200 ms, and render large validity effects at SOAs longer than 300 ms (Chica *et al.*, 2014; Olk *et al.*, 2014).

In addition to these results, an electroencephalogram (EEG) study used the N2-posterior-contralateral (N2pc) component onsets to quantify how long it took to orient attention endogenously from one visual object to another (Jenkins *et al.*, 2018). The N2pc component is an enhanced negativity at posterior electrodes contralateral to the visual field where the target object is located, and is considered a marker for attentional allocation to visual objects (Luck & Hillyard, 1994a). Jenkins *et al.* (2018) measured the difference of the onsets of N2pc elicited by two sequentially cued objects (T1 and T2), and compared these diferences when the objects were cued by arrow cues or by a central direction rule (i.e. orient attention from one object to another in a clockwise direction). The difference between N2pc onsets elicited by T1 and T2 would correspond to the time interval necessary for attention to be allocated from one object to another, thus the time it would take to orient attention either by an automatized process (triggered by arrow cues) or by a voluntary process (triggered by a central rule). They observed that shifting attention from T1 to T2 by using arrow cues (automatized process) corresponded to a difference of N2pc onsets of about 100 ms, in contrast, this difference of N2pc onsets when shifting attention using a clockwise rule (voluntary process) was of about 150 ms, indicating a much shorter time course for what was considered a voluntary orienting of attention compared to other studies. It could be that orienting attention from a clockwise rule could also be related to an automatized process since the spatial representation of this rule is also overlearned and could triggered fast shift responses.

Temporal course of endogenous orienting of attention still is a subject of inquiry especially because much of the evidence related to this attentional process comes from studies using the classical cueing task. In this task, the endogenous orienting of attention is investigated using conditions that requires a large amount of trials with repetitive presentation of a predictive cue followed by a target at the cued location. This repetitive strengthening of cue-target presentation could influence the processes involved in endogenous orienting. Therefore the studies reported here are relevant because they investigate if there is a distinction between the temporal course of a voluntary from an automatized process of endogenous orienting of attention by minimizing cue-target repetitive contiguous presentation during a variant of the classical cueing task.

The task used for the experiments reported here consisted of introducing a visual stimulus (anchor) between cue and target presentation in order to avoid or lessen the repetitive association between cue and target presentation at cued location. The anchor was presented at fixation point, and had to be reported after target detection response, thus having a role of a temporal marker to attentional shifts. The assumption was that subjects who had to report anchor would orient attention to cued location only after anchor presentation, thus avoiding a contiguous presentation of cue and target. The process involved in this orienting would require more voluntary control since orienting could only happen after anchor presentation. Therefore groups required to report or not to report anchor were compared by using different time intervals between anchor and target to verify the temporal course required for orienting of attention to occur.

The first experiment explored behavioral effects of different conditions for groups separated by anchor report or no anchor report condition, and predictive or non-predictive cue condition for four different SOAs (150, 300, 700 and 1000 ms). For the results, the anchor report and predictive cue condition group (AR-P) showed validity effect at almost all SOAs except for the shortest one (150 ms). In contrast, the anchor no-report and predictive cue condiion (AnR-P) group showed validity effect at all SOA including the shortest one. These results reveal that orienting attention for AR-P group, when reporting the anchor, requires a longer time interval in comparison to orienting attention when no anchor report is necessary (AnR-P group) indicating that the process involved in shifting attention for AR-P group would be slower and probably more voluntary.

This notion is also supported by the fact that a higher overall RT for AR-P group is significantly different from other groups, even for longer SOAs (700 and 1000 ms) suggesting that the requirement to report anchor would demand more attentional and cognitive resources. Higher RTs in shorter SOA (150 ms) and higher percentage of response errors for groups that reported anchor, especially for AR-P group, suggest that reporting anchor was a process that required a more controlled performance of target detection task. This seems plausible since it was required to decode different visual information presented rapidly and to maintain this information active in order to be used properly.

However, it was also possible that the time available for performing the task of detecting the target was longer for the groups that did not have to report anchor in comparison to the time available for the groups that reported anchor. Because the former groups were instructed to ignore anchor they could have used the entire time interval between cue and target, thus 250 ms more than the SOA (i.e. anchor-target onsets interval), to orient attention. This longer time interval would explain the difference of RTs and response errors between groups. Therefore, Experiment II was conducted to investigate whether shifts of attention would occur from cue presentation for group that did not report anchor (AnR) and from anchor for groups that did report anchor (AR). The aim was to compare orienting effects when the time intervals between cue-target onsets for AnR group were the same as the time intervals between anchor-target onsets for AR (both in a predictive cue condition).

Results showed a lack of validity effect at both SOAs (100 and 450 ms) for AnR group, but a significant validity effect at both SOAs (350 and 700 ms) for AR group. The lack of validity effect at 100 ms SOA for AnR group indicates that subjects were not able to orient attention at this time interval suggesting that anchor presentation, even if asked to be ignored, could also be a temporal marker for shifting attention. However, the lack of validity effect also observed at the long SOA (450 ms) suggests that subjects did not use the predictive cue during the task. One hypothesis could be that because less than half of trials in the task (150 trials) would have the conditions (i.e. predictive cues with a sufficient time interval for orienting to occur) to allow for strengthening of the association between cue and target location then cue information would be weak and subjects would not use the cue to orient attention. To test this hypothesis a experiment could be conducted with longer SOAs or by increasing the number of trials so association between cue and target would be more strengthened. Results of both experiments suggest that orienting of attention occurs after presentation of anchor for groups that report anchor and for groups that does not. Therefore behavioral effects comparisons between groups can be made using the same SOAs.

In summary, this study give support to the hypothesis that cue-target associations are strengthened during classical cueing task questioning which processes, voluntary or automatized, would be involved during control of endogenous orienting of attention. Results reported here indicate that avoiding repeated cue-target contiguous presentation interfered with orienting of attention at 150 ms SOA. However if cue-target associations can be strengthened during task then orienting of attention does occur at 150 ms SOA. These results support the hypothesis that an automatized (faster) process could arise from performing a task with repeated trials, and indicate that a more voluntary (slower) process of orienting attention requires an SOA longer than 150 ms.

4. Chapter II

Voluntary endogenous orienting of attention: an analysis of Event-Related Potentials components during performance in a variant of the cueing task

This study aimed at investigating the temporal course and exploring the electrophysiology of voluntary endogenous orienting of attention by analyzing behavioral effects and electroencephalographic (EEG) recordings when using a variant of the classical cueing task. This variant consisted of establishing in a trial-by-trial manner a rule to follow in order to use a new cue to orient attention on each trial. This way it would be possible to avoid repetitive presentations of cue followed by a target at cued location without visually interfering with sensory and cognitive processes during orienting of attention. The design of this task was relevant for the analysis of event-related potentials (ERP) components related to the underlying neural mechanisms involved with orienting of attention and its effects on sensory systems. The EEG study was mainly exploratory aiming at analyzing ERP components that has being observed and related to endogenous orienting of attention by different studies. Therefore, it was expected to observe some of these components, but with different modulations of amplitude or latency. Furthermore, a behavioral study was also conducted using the same task to analyze the effects of short, medium and long SOA on the performance of discrimination of cued and uncued targets. The hypothesis was that the trial-by-trial cue would trigger a slower voluntary shift of attention, hence at short SOA no validity effects would be observed.

Voluntary endogenous orienting of attention: an analysis of Event-Related Potentials components during performance in a variant of the cueing task

Jordão, E.M.A.[1]*, **Xavier, G.F.**[1] and **Mangun, G.R.**[2]

[1] Department of Physiology, Institute of Biosciences, University of São Paulo, São Paulo, Brazil
[2] Center for Mind and Brain, University of California, Davis, USA
*Corresponding author: elisa.jordao@usp.br

Abstract

Key-words: visuo-spatial attention; voluntary endogenous orienting of attention; event-related potentials

Visuo-spatial cueing tasks using symbolic cues are believed to engage voluntary orienting of attention. However, repeated associations of symbolic cues to a target-relevant location could lead to an automatic or involuntary process for orienting of attention, thus generating confounding effects. In order to avoid cue-target associations we designed a cueing task where target location was cued by a novel cue in each trial, thus precluding automatic processes. This variant consisted of establishing in a trial-by-trial manner a rule to follow in order to establish how to use a new cue to orient attention on each trial. Cues could be either congruent or incongruent with the previous rule. The temporal course of orienting of attention was evaluated using three different time intervals between the appearance of the cue and the target. Significant validity effect for reaction times and accuracy revealed that orienting of attention occurred even at short SOAs. However, when cues were incongruent (different from the instruction) reaction times increased and accuracy decreased thus indicating a difficulty in attentional shift. Analysis comprised Event-Related Potential (ERP) components after the cue presentation, including EDAN, ADAN, LDAP and a N2pc-like effect , and ERPs related to target, including P1 and N2pc. The contralateral LDAP component was observed at posterior electrodes. In addition, a small but significant early visual effect, P1 modulation, was observed after target presentation confirming an early modulation of visual processing at the attended location. Results also showed that incongruent cues modulate the N2 component at anterior electrodes, and could be related to a small modulation of the SPCN post-target component that reflect the use of visual working memory. Those results show that voluntary orienting attention process can occur at 250 ms time interval, but this process can be hindered when a conflicting information is used to orient attention rendering poorer performance of a task.

1. Introduction

Orienting of attention in humans is believed to occur in at least two different ways: (1) endogenously (or voluntarily) or (2) exogenously (or automatically). This view primarily stems from behavioral studies using visuospatial cueing tasks. They reveal that the speed and accuracy of responses to targets vary depending on different time intervals between presentation of a cue and a target (Stimulus-onset assynchronies – SOA), and how the target is cued, either by a peripheral and salient cue or a central and symbolic cue (Jonides, 1981; Muller & Rabbitt, 1989). Put simply, when a salient stimulus appears in the visual field (exogenous cue) it automatically and rapidly (tens of milliseconds) attracts attention to that location in space regardless of whether that stimulus carries any information relevant to the task. In contrast, a central endogenous cue (e.g., an arrow), engages a voluntary, top-down orienting of attention that requires effort and takes more time (hundreds of milliseconds) (Jonides, 1981; Posner & Cohen, 1984). A cueing effect (or validity effect) is observed when the reaction time (RT) to the cued target (valid cue) is faster than the reaction time to an uncued target (invalid cue) which indicate that orienting attention to the location of target presentation speeds its detection (Posner, 1980). Therefore, in a cueing task a target could be cued by a peripheral cue that would trigger a fast shift of attention to it, or it could be cued by a symbolic cue which would involve a slower process of shifting attention to the cued location.

However, recent studies have challenged this dichotomy of how attentional control occurs (Awh *et al*., 2012; Theeuwes, 2018; Ristic et al., 2002). By using spatially relevant overlearned stimuli, like arrows (Ristic & Kingstone, 2012; Friesen & Kingstone, 1998), or by training an arbitrary visual stimuli to be associated with a location in space (Guzon *et al.*, 2010; Dodd & Wilson, 2009) these studies have shown that symbolic cues may also lead to fast orienting of attention as if it was automatic. This evidence indicates that associations between symbolic cues and the direction they indicate may involve an automatized process in orienting of attention.

In this context it could be questioned if an automatized process, rather than a voluntary, would be involved in endogenous orienting of attention in a classical cueing task. Because predictive symbolic cues indicate correctly the location of an impeding target usually in 80% of trials it is possible that this repeated presentation of cue and target contributes to an automatization of orienting of attention. This would mean that the evidence about voluntary control of endogenous orienting of attention from cueing tasks could be also related to an automatized control of orienting of attention. Concerning this issue some researchers believe that to determine whether there is true voluntary control of attention it is necessary to change the attentional set on a trial-by-trial basis during an attentional task (Theeuwes, 2018). Therefore, to test this hypothesis a variant of the visuo-spatial cueing task was developed aiming to avoid cue-target associations by stipulating a novel cue to orient attention on each trial of the task, thus making it impossible to associate a particular symbolic cue to a spatial location.

Behavioral studies using different SOAs are usually conducted to investigate processes involved in orienting of attention. As mentioned above, an overlearned symbolic cue like an arrow triggers a fast shift of attention. That is, a target cued by an arrow could be detected faster than an uncued target even if the arrows are non-predictive of the targets, and at SOAs as short as 100 ms (Ristic *et al.,* 2002). Therefore, it is believed that an automatized process is involved with this endogenous orienting of attention which allow for cueing effects to be observed at this short SOA. In contrast, voluntary orienting of attention would occur only at longer SOAs (~300 ms) (Chica *et al*., 2014; Posner, 1980; Muller & Rabitt, 1989). A voluntary shift of attention would require a longer time because the symbolic cue would have to be interpreted first before the shift occured, thus involving more cognitive resources (Chica *et al.*, 2014). Olk *et al*. (2014) observed distinct cueing effects for different types of symbolic cues when using diferent SOAs. Large cueing effects (more than 25 ms difference between cued and uncued target RTs) were observed at 100, 450 and 800 ms SOAs when attention was oriented by arrow cues. However, colour cues or number cues associated with a spatial location were related to a smaller cueing effects (10 ms) at 100 ms SOA compared to the cueing effects at 450 and 800 ms SOA (about 20 ms). These cueing differences between short and long SOAs could account for a longer time course required for a more voluntary orienting of attention to occur. Therefore, the behavioral study conducted here considered a similar approach to understand the time course of the processes involved in endogenous orienting attention by a novel cue on each trial.

Electroencephalography (EEG) recordings when performing a cognitive task allows an investigation of the underlying neural mechanisms related to cognitive processes. A common and very useful methodology, called Event-Related Potential (ERP), is to average EEG signals from many trials time locked to an especific visual stimulus, such as a cue or a target in order to observe modulatory effects of neural activities during attentional processes. Prior electrophysiological studies using ERPs analysis have investigated the mechanisms and time course of neural activity involved in endogenous orienting of attention. Studies reported enhanced negativity or positivity of neural activity at the hemisphere contralateral to the cued visual hemifield compared to neural activity at the ipsilateral hemisphere after symbolic cue presentation (Harter *et al*., 1989; Hopf & Mangun, 2000; Nobre *et al*., 2000; van Velzen & Eimer, 2003). These ERP components following cue presentation were described as the Early Directing Attention Negativity (EDAN) enhanced negativity at posterior electrodes with onset at about 200 ms after cue, and the Anterior Directing Attention Negativity (ADAN) at anterior electrodes onsetting at about 300 ms after cue, and they are considered to be related to the processes of initiating of orienting of attention (Hopf & Mangun, 2000; Praamstra *et al.*, 2005). The Late Directing Attention Positivity (LDAP) an enhanced positivity at posterior electrodes with onset at about 500 ms after cueing is considered to be related to the preparatory activity at the contralateral visual cortex from attentional orienting (Hopf & Mangun, 2000; Nobre *et al*., 2000). These modulatory neural activities could be considered as indexes related to an endogenous orienting of attention, thus differences in latency or amplitude of these ERP components could indicate variations on the processes involved in orienting attention.

In addition to these components, other ERP components related to target presentation are modulated by attentional allocation. Mangun & Hillyard (1987) showed that spatial allocation of visual attention to a unilateral target is indexed by amplitude modulations of early (between 80-180 ms after target) sensory-evoked positive (P1) and negative (N1) components at occipital electrodes. That is, there are increased amplitudes of brain potentials when a visual stimuli is presented at attended locations. Furthermore, Woodman *et al.* (2009) and Kiss *et al.* (2008) evaluated the N2pc component (negative posterior-contralateral around 200 ms after target is presented) at posterior electrodes, commonly related to selective processing of target stimulus presented among non-target stimuli (target array), in a cueing spatial task. Kiss *et al.* (2008), reported no difference in N2pc modulation when target was cued in comparison to non-cued target indicating that this component would not be related to sensorial modulatory activity involved when attention is shift to a location. They did observe components related to shift of attention and preparatory visual activity after cue presentation like ADAN and LDAP which indicated that attentional orienting had occured. In contrast, Woodman *et al.* (2009) reported different results when also analyzing cueing effects for a target among bilateral non-targets. They observed a N2pc-like effect, a negative deflection rather than a positivite one as expected for LDAP, elicited 200 ms before target array was presented. No EDAN, ADAN or LDAP components was observed. In relation to target, they also observed a N2pc modulation at about 270 ms after target array presentation similar to Kiss *et al.* (2008) results. They interpreted these results as an indicative of an anticipatory N2pc component related to an attentional shift to objects, and not locations, since this effect was only present when an array of placeholders were present as static standing background. Futheremore, they suggest that the LDAP component could have been absent because of the negativity related to this preparatory selection of objects related to the N2pc-like component.

The studies mentioned above used arrows or words as cues to investigate these components. Therefore, it would be interesting to analyze ERP components during the trial-by-trial cueing task with a novel cue on each trial to explore modulations of components that could be elicited after presentation of the novel cue and after presentation of a target array. Here we report two experiments. The first study investigated the electrophysiological ERP components related to these processes. In the second one, a behavioral study focused on the time course of processes involved in the task.

2. Behavioral study

Behavioral studies suggest that endogenous orienting of attention effects woud be observed at SOAs as short as 300 ms (Chica *et al*., 2014; Muller & Rabitt, 1989). This time would be required because symbolic cues have to be interpreted in order to trigger an orienting response. Therefore, the time that the cue is displayed is also relevant for processing its meaning so that orienting of attention can occur accordingly. The time required for interpretation of cue may vary depending on the type of cue (Chica *et al*., 2014, Olk *et al*., 2014) with spatially neutral cues requiering more time than spatially overlearned cues. For the study reported here, the decision to use 200 ms for presentation of cue relied on results of other studies that showed that this time interval would be sufficient for interpretation of spatially neutral symbolic cues (Bengson *et al.,* 2014). Also, three time intervals between cue and target onsets (250, 300 and 400 ms SOA) were used in order to analyze the time course of orienting of attention in this task. Our hypothesis were that, because cueing in a trial-by-trial basis would involve a more controlled, and thus voluntary orienting of attention, attentional shifts to the instructed side would require a longer time (>250 ms) resulting in a smaller or lack of validity effect at 250 ms SOA. In contrast, with more time to shift attention towards the cued location such as at 400 ms SOA, RTs related to valid cues would be faster then RTs to invalid cues resulting in larger validity effects.

2.1. Material and methods

2.1.1. Participants

Fifteen undergraduate students from University of California - Davis participated in the behavioral study being all right-handed and ten female. They all signed a consent form. Handedness was evaluated according to the Edinburgh handedness questionnaire. All subjects had normal or corrected to normal vision. No participants were excluded from behavioral study.

2.1.2. Procedure

A scheme representing the task used in both studies (behavioral and EEG) is shown in Figure 5. It consisted of presenting a rule on how to use the cue. This rule (2º x 2º) was a three-digit number accompanied by the word "RIGHT" or "LEFT". After this instruction, a cue (2º x 2º) was presented close to fixation point (0.4º above center) which could be either the same three-digit number or a different three-digit number as the number shown for the rule indicating the side to which participants had to attend. The same three-digit number indicated that the subject had to follow te rule, that is orient attention towards the side instructed by the rule (i.e. the word). If it was a different three-digit number then the opposite side instructed by the rule had to be attended. The frequency of same and different three-digit numbers were counterbalanced. A target was presented either on the left or right side at the midline of fixation point together with distractors after one of three possible SOAs (250, 300 and 400 ms). The target array consisted of five C shape bilateral distractors with the gap either to the left or right, and the target consisted of a C shape with the gap UP or DOWN (0.6º x 0.6º). Participants had to discriminate whether the gap of the target was UP or DOWN by pressing one of two buttons in a joystick. The set of distractors and target were presented inside placeholders (0.7º x 0.7º) - three squares on each side (8.8º from the vertical meridian; 3.13º above or bellow from the horizontal meridian). Stimuli were presented in an LCD display (ViewPixx) with a 120Hz refresh rate.

Data was collected in a soundproof room with a dim light. Participants sat in a comfortable armchair with their eyes positioned at a distance of 80 cm from the display. Eye movements were monitored and recorded using an eye-tracker (EyeLink 1000 plus). The behavioral study consisted of 8 blocks with 102 trials each. 75% of trials had valid cues (target presented where cue indicated), and 25% of trials had invalid cues. Reaction time and discrimination of target were analyzed by conducting a repeated measures analysis of variance (ANOVA) using the JASP software.

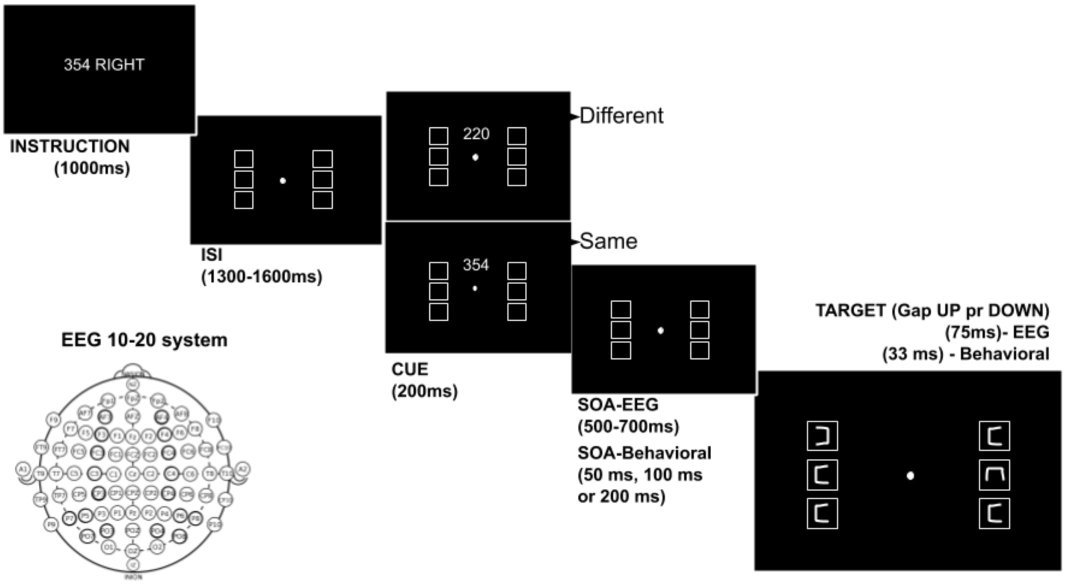

Figure 1. Task schema for both behavioral and EEG study showing a valid cue condition if the cue would be the same-number (354), or invalid cue condition if the cue would be a different-number (220). No number was used more than once. On bottom left is the international 10-20 system for location of electrodes in EEG with black marked electrodes (AF3, AF4, F3, F4, FC3, FC4, C3, C4, CP3, CP4, P5, P6, P7, P8, PO3, PO4, PO7, PO8) used on the analysis. Size of stimuli is not in scale.

2.2. Results

Trials exhibiting RTs lower than 100 ms or higher than 2000 ms were excluded from analysis. Mean RTs and mean percentage of accuracy as a function of type of cue related to the instruction (same or different number), SOA (250, 300 and 400 ms) and validity (valid or invalid cue) are shown in Figure 2 and Figure 3, respectively. Data were analyzed considering the same factors. It is important to note that the experiment was designed to evaluate the cues altogether without considering type of cues because the expected effect was related to using a novel cue for each trial independently of it being incongruent or congruent. However the effect of type of cue was further investigated since participants would consistently report having more difficulty in orienting attention when cue number was incongruent with the rule number. Therefore, it was possible to analyze the data considering the type of cue since it was counterbalanced.

For RTs, as expected, repeated measures ANOVA revealed significant main effects for SOA ($F_{2,26} = 10.56$; $p<0.001$;$\eta^2=0.448$) and validity ($F_{1,13} = 12.32$; $p=0.004$;$\eta^2=0.486$), but no main effect for type of cue ($F_{1,13} = 2.47$; $p=0.14$;$\eta^2=0.160$). However, subjects reported it was harder to use a different-number cue as compared to the same-number cue to orient their attention. A marginal effect was revealed for interaction between type of cue and validity ($F_{1,13}$ = 4.14; p=0.063;η^2=0.242) indicating that validity effect for targets cued by different-number cues were smaller in comparison to validity effect for same-number cues. No interaction effect between SOA and validity was found, thus indicating that validity effect is independent of the time intervals between cue and target used in the experiment contrary to the prediction of observing a lack of validity effect at the shortest SOA. *Post-hoc* Bonferroni test showed that RTs at the longest SOA (400 ms) were significantly smaller compared to RTs at the shortest SOA and medium SOA ($p < 0.002$) indicating a faster response when participants had a longer time interval between cue and target.

Analysis of target accuracy complemented the results from RTs. Main effects of type of cue ($F_{1,13}$ = 17.03; p=0.001;η^2=0.567) and validity ($F_{1,13}$ = 13.46; p=0.003; η^2=0.509) were revealed. Main effect of SOA was near significant ($F_{2,26}$ = 3.18; p=0.058;η^2=0.197) indicating a tendency of higher accuracy for longer SOAs. Moreover, an interaction effect was revealed between type of cue and validity ($F_{1,13}$ = 7.05; p=0.02;η^2=0.352). Thus indicating a higher accuracy for validly cued targets compared to invalidly cued targets as well as a higher accuracy when targets are cued by same-number cue compared to different-number cues, and a smaller validity effect when targets are cued by different-number cue compared to same-number cue.

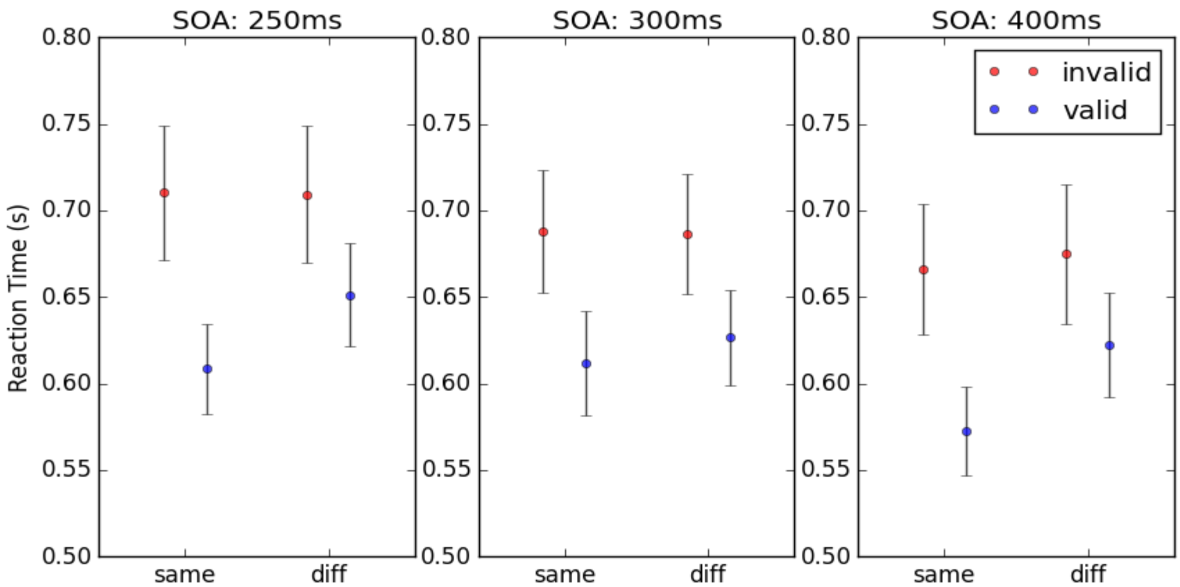

Figure 2. Mean (±SD) reaction time in seconds as a fuction of SOA (250, 300 and 450 ms), type of cue (same-number or different-number cue), and cue validity (valid (blue) or invalid (red)) of all participants. Proportion of valid cues in the task was 75%.

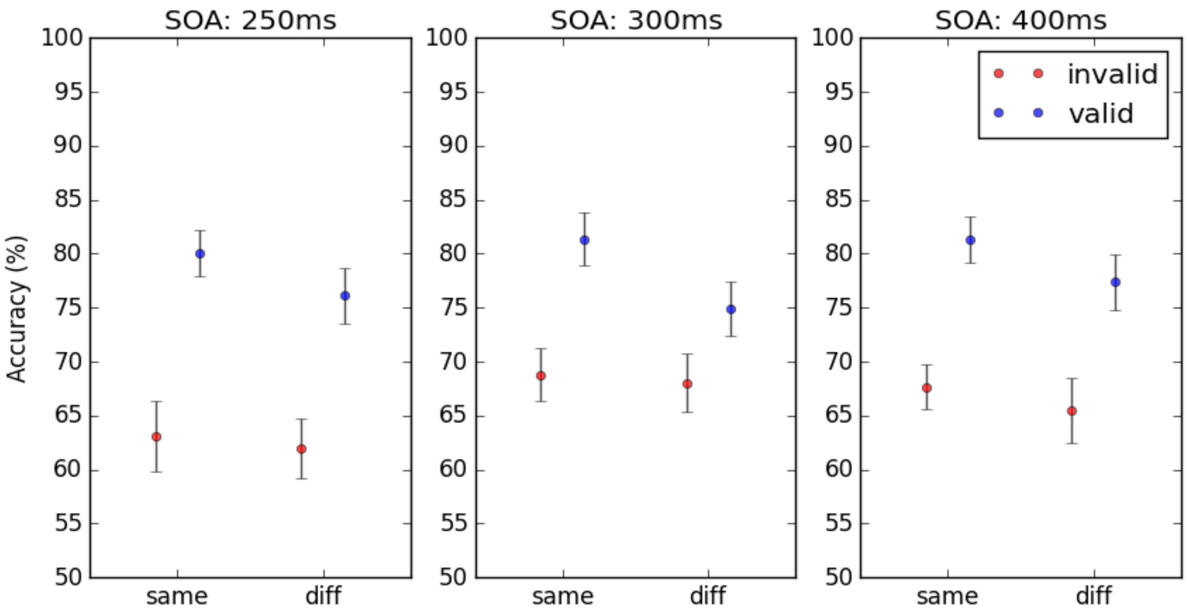

Figure 3. Mean (±SD) percentage of target accuracy as a fuction of SOA (250, 300 and 450 ms), type of cue (same-number or different-number cue), and cue validity (valid (blue) or invalid (red)) of all participants. Proportion of valid cues in the task was 75%.

In summary, results indicate that orienting of attention does occur at 250, 300 and 400 ms SOA when a novel cue is used in a tria-by-trial manner demonstrated by validity effects for RTs and accuracy independently of SOAs. Furthermore, results also showed that the validity effect interact with the types of cues indicating that the validity effect for same-number cues is larger then the validity effect for different-number cues. This suggests that the orienting of attention process triggered by a cue that is incongruent with the rule (different-number) seems to be more costly for task performance than the process of orienting attention by same-number cue as revealed by higher RTs and lower accuracy for different-number cues. Also, results indicate that the processes involved in orienting of attention by congruent or incongruent cues in a trial-by-trial manner differ from each other in relation to the validity effect size.

The behavioral data shows interesting results related to orienting attention by a cue that has its directional meaning established by a rule on each trial, however there were limitations in understanding these processes by using different SOAs. As mentioned before, the time of cue presentation is relavent for processing its meaning which limit how short an SOA could be. Therefore in order to observe a lack of validity effect with a shorter SOA it would be necessary to decrease the presentation cue so the SOA could be shortened perhaps to 150 ms.

To further understand the processes that could be involved in this task when using a novel cue in each trial another study was conducted to investigate the underlying neural mechanisms related to the cognitive processes of this task.

3. EEG study

This study investigated ERP components related to the processes of orienting of attention triggered by cue presentation, namely EDAN, ADAN, LDAP and N2pc-like, and ERP components related to target presentation processes modulated by attention, such as P1, N1 and N2pc. Predictions were that a more voluntary orienting of attention would be related to late ERP components after cue presentation because of the time required for controlled processes to unfold like the interpretation of cue. Thus, it was investigated which of the two components reported to occur before target presentation, LDAP (Hopf & Mangun, 2000) or N2pc-like (Woodman *et al.*, 2009), would be related to shifts of attention in a trial-by-trial manner. Additionally, it was explored if activity at anterior sites (e.g. frontal cortex) would be observed at earlier stages of orienting of attention since this area is often involved with voluntary control of attention. Thus it was expected to observe components like ADAN that was reported to involve the activity for initiation of endogenous orienting of attention (Praamstra *et al.*, 2005). In relation to target presentation the attentional P1/N1 modulations were expected since they reflect an enhancement of visual stimuli processing when target is presented at cued locations. The N2pc component was also explored since it is considered to be related to the deployment of visual-spatial attention but also to spatially selective processing of targets and/or attentional suppression of surrounding distractors.

3.1. Material and method

3.1.1. Participants

Twenty-five undergraduate students from University of California - Davis participated in the EEG study. Fourteen subjects were excluded from EEG analysis either because of excessive eye blinks, eye movements, or noisy data.Therefore data were analyzed from eleven subjects being seven female and one left-handed. Handedness was evaluated according to the Edinburgh handedness questionnaire. All subjects had normal or corrected to normal vision. They all signed an informed consent form.

3.1.2. Procedure

The task was the same as the one described in the prior experiment, and data was collected in the same conditions. Participants did 8 blocks of 68 trials each, and 10% of trials were invalid to check for validity effect. A jittered SOA between 700 ms to 900 ms was used. Note that a substantially elevation of SOA was necessary for analysis of ERP components after cue presentation without an interference of components related to target presentation. Therefore processes that could be involved with faster attentional shifts was not evaluated here.

3.1.3. Recordings and analysis

The EEG was recorded using an Easycap 2 x 32-channels active electrodes (actiCap, Brainproducts). Scalp channels were referenced to the Fcz during online recording(re-reference to average mastoids was applied after data recording) and impedances were kept below 20 kΩ. An online low-pass filter of 100 Hz was used with a Synamps II amplifier with Scan 4.2 software. Two filters were applied later to the recorded data, a low-pass of 30 Hz and a high-pass of 0.1 Hz. Data were recorded in DC at a sampling rate of 1000 Hz. To monitor horizontal eye movements, bipolar electrodes were placed on the outer left and right canthus of the eyes. To monitor eye blinks, frontal electrodes were used. We only analyzed participants who had less than 25% of trials rejected during artifacts rejection analysis. Residual eye movement that resulted in voltage deflections lower than 3.2 μV (corresponding to an ocular deviation of ±0.2°) were accepted. EEG data preprocessing and analysis were run on EEGlab (Swartz Center for Computational Neuroscience) and ERPlab (UC-Davis Center for Mind & Brain).

For analysis of brain activity in relation to cue and target presentation, EEG data were epoched -200 ms to +1600 ms cue onset and -200 ms to 800 ms target onset, and both baseline corrected using the 200 ms data before cue or target onset. Contralateral versus ipsilateral effects were analyzed focusing on time intervals of 300-500 ms and 500-700 ms after cue onset (related to ADAN, and LDAP or N2pc-like components, respectively), and post-target time intervals of 80-120 ms (related to P1/N1), 200-300 ms (related to N2pc) and 400-600 ms since there was an indication of a contra-ipsilateral effect perhaps related to sustained posterior contralateral negativity (SPCN). The modulation effects were measured as the difference between electrode sites contralateral and ipsilateral to the cued location. Statistical analysis was conducted using repeated measures analysis of variance (ANOVA) for each participant mean amplitude of contralateral and ipsilateral waveforms during time intervals stipulated previously for each component. Sphericity checks with Greenhouse-Geisser correction was applied when necessary.

3.2. Results and discussion

Behavioral data were analyzed similarly to the first experiment. Repeated measures ANOVA included type of cue (same-number and different-number cue) x validity (valid and invalid) for RTs and accuracy. Both RT ($F_{1,10}$ = 20.48; p=0.001;η^2=0.672) and accuracy ($F_{1,10}$ = 20.45; p=0.001;η^2=0.672) exhibited main significant effects for validity. In addition, relative to type of cue there was a significant effect for accuracy ($F_{1,10}$ = 8.43; p=0.016;η^2=0.458), and a near to significant effect for RT ($F_{1,10}$ = 3.85; p=0.078;η^2=0.278). No interaction was revealed. These results replicate previous data showing validity effect for both same and different-number cues, but with significant difference between these cues. Again we observed that orienting of attention by different-number cue are related to lower accuracies and higher RTs suggesting that orienting one's attention by this cue demands more resources than orienting of attention by same-number cue.

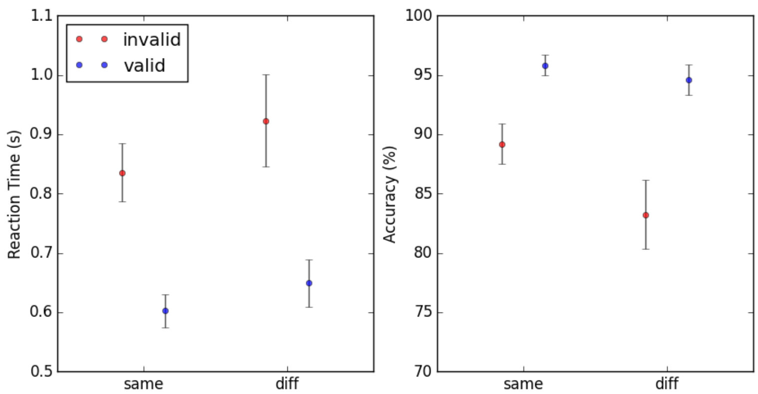

Figure 4. Mean (±SD) RT (sec) and target accuracy (%) for same-number cue (same) or different-number cue (diff) when cue is valid (blue) or invalid(red) of all participants. Proportion of valid cues in the task was 90%.

The averaged ERPs waveforms evoked by cues of all participants are shown in Figure 5. No lateralized effects were observed until approximately 500 ms. At this time point until target presentation (jittered SOA between 700 - 900 ms) the hemisphere contralateral to the cued location became more positive in comparison to the ipsilateral hemisphere at posterior electrodes. This positivity at this time period is typically observed in spatial cueing task, and described as a Late Directing Attention Positivity - LDAP (Harter & Anllo-Vento, 1991; Hopf & Mangun, 2000). Repeated measures ANOVA considering laterality (contralateral and ipsilateral) and electrodes (F3/4, C3/4, CP3/4, P7/8, P5/6 and PO7/8) revealed a main effect of laterality (F1,10 = 11.86; p=0.006;η^2=0.543), and electrodes (F5,50 = 13.79; p<0.001;η^2=0.580, ε=0.303). Analysis also showed a significant interaction effect (F5,50 = 8.49; p<0.001;η^2=0.459) which is explained by a significant enhanced positivity of contralateral compared with ipsilateral at posterior electrodes (P7/8, P5/6 and PO7/8), but not at fronto-central electrodes (F3/4, C3/4 and CP3/4). This was corroborated by a separate analysis of mean amplitude at anterior and posterior electrodes showing a laterality main effect for posterior eletrodes (F1,10 = 18.49; p=0.002; η^2=0.649), but a lack of laterality main effect for fronto-central electrodes (F1,10 = 0.159; p=0.698; η^2=0.016). No other lateralized effect like EDAN or ADAN were observed. These results support the hypothesis of a late effect of directional spatial attention when involving a more voluntary process of orienting attention. However, a lack of anterior effects was unexpected especially with behavioral results indicating that attentional shifts by using a different-number cue would perhaps require more attentional control and cognitive resources.

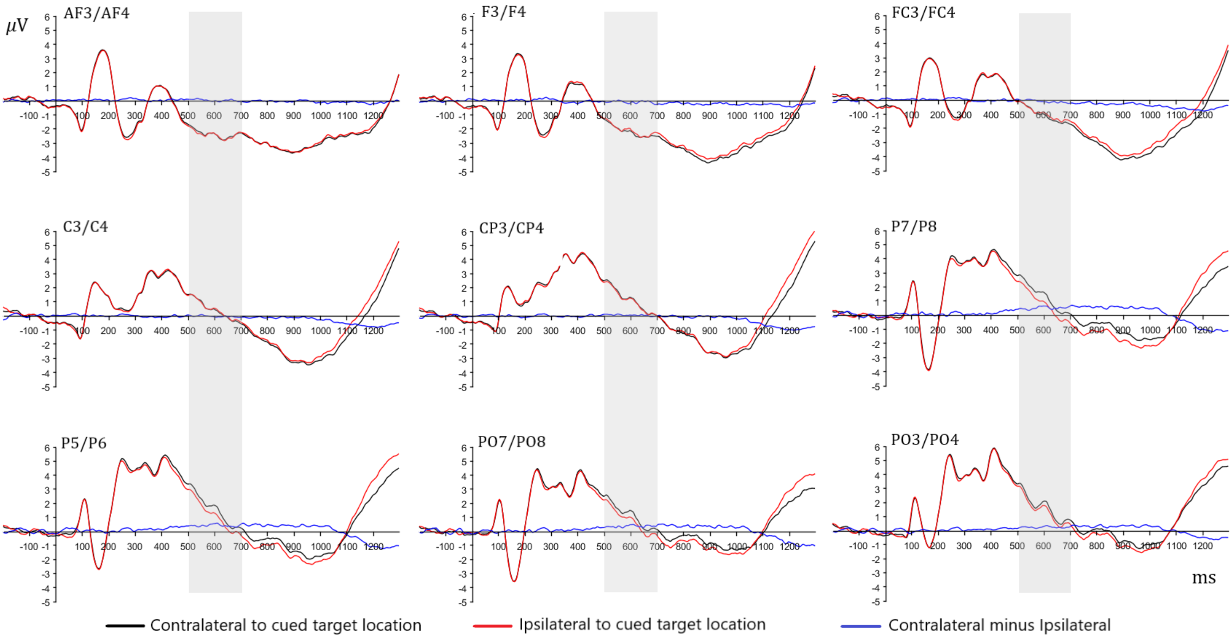

Figure 5. Grand average (N=11) contralateral (black line), ipsilateral (red line) and contra minus ipsilateral (blue line) waveforms time-locked to the cue-onset. The shaded region shows the time window used to quantify the LDAP. Waveforms are shown from pairs of selected electrodes covering the posterior-central-anterior extent of the recordings. The electrode montage used for the experiment is show in Figure 1 (bottom-left) with the electrodes used for all waveforms and analysis marked black.

Analysis of waveforms relative to the type of cue (Same or Different) without computing contra and ipsilateral differences were also conducted (Figure 6) because of differences observed in behavioral data. As shown on Figure 6 there is a marked voltage difference between same-number cue and different-number cue waveforms during time period from 250 to 350 ms after cue. For the analysis it was employed central electrodes (Fz, Cz, Pz, Oz, CPz, POz) since this component was not lateralized. A repeated measures ANOVA considering type of cue (same-number and different-number cue) and electrodes (Fz, Cz, Pz, Oz, CPz, POz) revealed a main effect for type of cue ($F_{1,10} = 10.62$; $p=0.009$; $\eta^2=0.515$) and electrodes ($F_{5,50} = 11.38$; $p=0.003$; $\eta^2=0.525$, $\varepsilon=0.284$). No interaction between type of cue and electrode was revealed indicating that mean voltage amplitudes for same or different-number cues were significantly different in all electrodes, even though this difference seems to decrease from anterior to posterior electrodes. The enhanced negativity at anterior electrodes could be related to processing a conflict and inhibiting a predominant shift of attention response caused by different-number cues. This hypothesis is based on studies that indicate an negative deflection around 200 ms, a modulation of the N2 component, as an index of resolving conflict, which refers to a simultaneous activation of competing stimulus or response option, in flanker task and inhibiting responses on go/no-go task (Bartholow *et al.*, 2005; Folstein & Von Petten, 2008). Evidence from a flanker task showed an increased N2 amplitude at fronto-central electrodes in incongruent trials (i.e. when target is different from flanking stimuli), but not in congruent trials (i.e. when the target is the same as the flanking stimuli), and further propose that the anterior cingulate cortex (ACC) would be the source of this effect since it would be involved in evaluative control functions (Larson *et al.*, 2014).

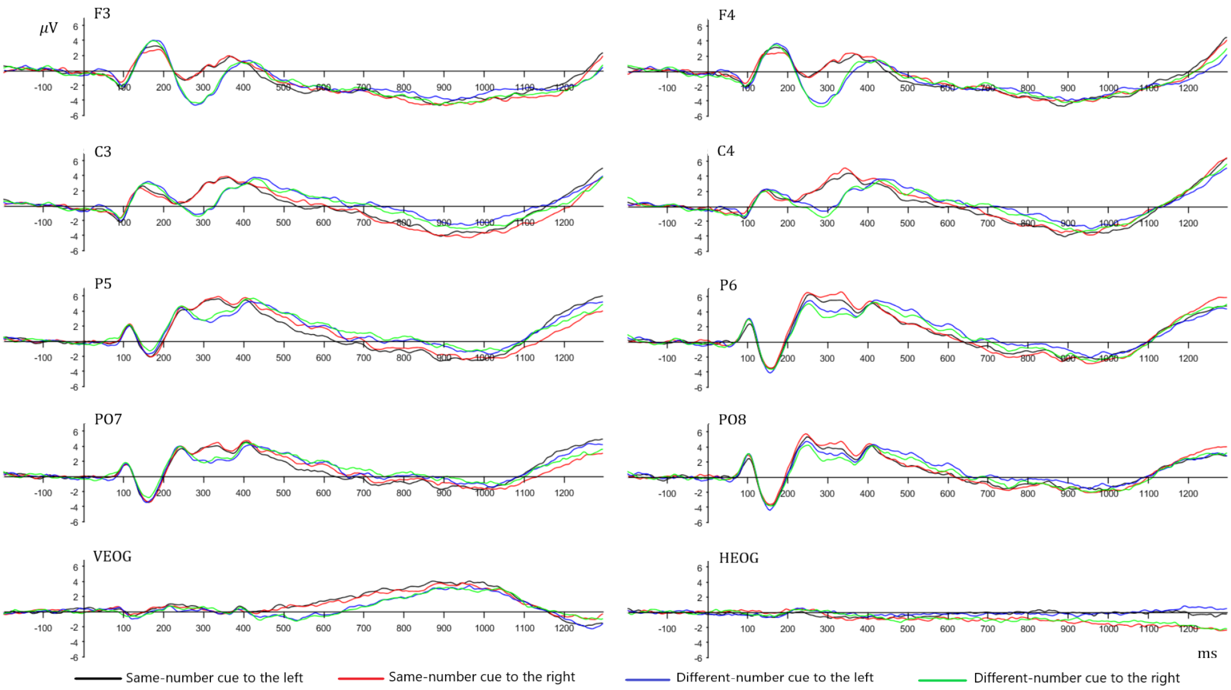

Figure 6. Grand average (N=11) waveforms time-locked to the cue-onset as a function of type of cue (same-number and different-number) and side of direction of attention (left and right). Waveforms are shown from selected electrodes covering the posterior-central-anterior extent of the recordings. Horizontal eye movements (HEOG) and Vertical eye movements (VEOG). The electrode montage used for the experiment is show in Figure 1 (bottom-left) with the electrodes used for all waveforms and analysis marked black.

For the analysis of ERPs components time-locked to target array presentation it was also computed contralateral and ipsilateral waveforms (Figure 7), and conducted a repeated measures ANOVA using laterality and electrodes as factors.

P1 component was first analyzed including six pairs of electrodes (AF3/4, FC3/4, CP3/4, P7/8, P5/6 and PO3/4). Repeated measures ANOVA revealed electrodes main effect ($F_{5,50}=5.27$; $p=0.027$;$\eta^2=0.345$, $\varepsilon=0.289$), but no laterality main effect. There was a significant interaction effect between laterality and electrodes ($F_{5,50}=3.89$; $p=0.05$;$\eta^2=0.281$, $\varepsilon=0.317$). Therefore, it was conducted a second separated analysis of the posterior electrodes (P/5/6, P7/8 and PO3/4) and the anterior electrodes (AF3/4, FC3/4, CP3/4). Not surprisingly a significant laterality effect was revealed for posterior electrodes ($F_{1,10}=4.87$; $p=0.05$;$\eta^2=0.328$) analysis, with no electrode main effect or interaction effect between laterality and electrode. For anterior electrodes no significant laterality effect was found, but electrodes main effect, and laterality x electrodes interaction was revealed due to a small modulation at C3/4 and CP3/4 electrodes. These mean amplitude analysis indicate that there was a positivity enhancement at around 80 to 120 ms after target and located at posterior electrodes most likely being a P1 effect. Therefore we found evidence, consistent with previous studies, that shows a modulation of early extrastriate-generated P1 component.

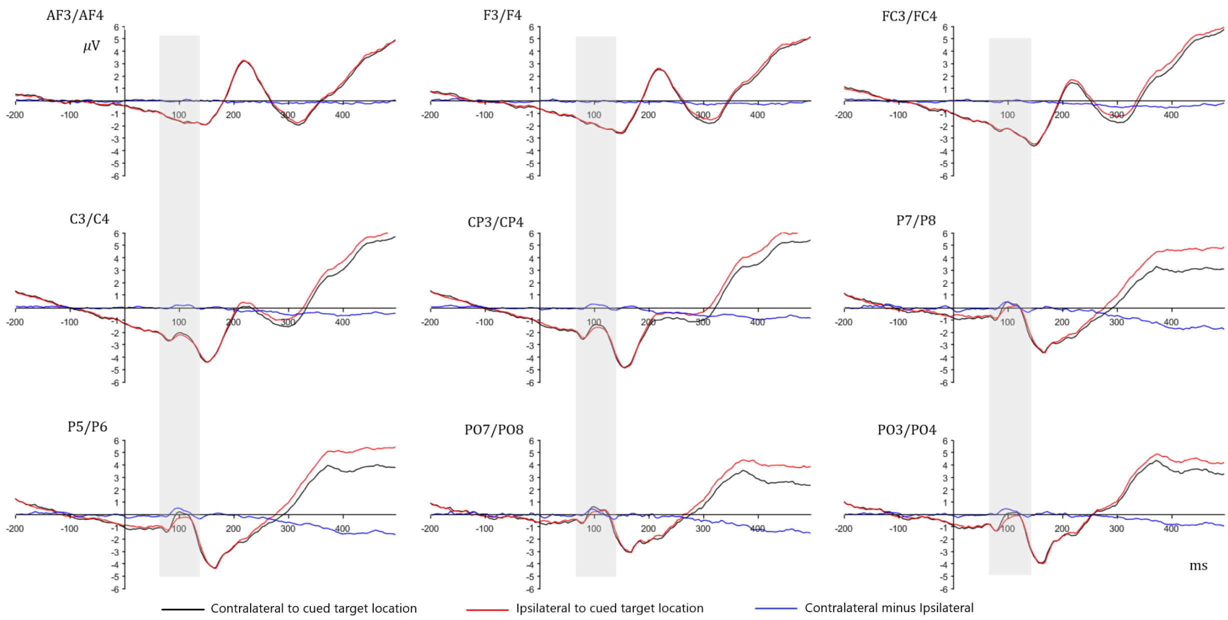

Figure 7. Grand average (N=11) contralateral (black line), ipsilateral (red lines) and contra minus ipsilateral (blue lines) waveforms time-locked to the target array. Waveforms are shown from pairs of selected electrodes covering the posterior-central-anterior extent of the recordings. The shaded region shows the time window used to quantify the P1. The electrode montage used for the experiment is show in Figure 1 (bottom-left) with the electrodes used for all waveforms and analysis marked black.

Another component analyzed from waveforms time-locked to target was N2pc, which is a negativity enhancement observed at occipital electrodes contralateral to the visual field of target presentation in a bilateral target array, and it is related to the selective attention process of a target among non-targets and/or the attentional suppression process of non-targets (Luck & Hillyard, 1994a; Luck & Hillyard, 1994b). Some studies analyzed the N2pc component when target among distractors was cued by symbolic cues and showed a clear presence of this component around 250 ms after a target array presentation (Kiss *et al.*, 2008; Woodman *et al.*, 2009). In the present study the N2pc component was not observed. Statistical analysis did not revealed a significant main effect of contralaterality at posterior electrodes (P7/8, P5/6, PO3/4 and PO7/8) at 200-300 ms after target presentation. In comparison to the previously mentioned studies the target array displayed in this task had much less distractors (5 non-targets in comparison to 11 non-tagets), and the location of presentation of the C-shape target was fixed at the middle box on each side, thus not requiring a search for the target. Therefore it is possible that no spatial selective processing occurred after target presentation which support an effect of a strong shift of attention to a spatial location before target presentation.

In relation to the type of cue used for orienting of attention, it was also conducted an analysis of the SPCN component after target presentation. The SPCN is also a lateralized component seen at occipital sites contralateral to the presentation of target stimulus and has been related to maintenance of visual information in working memory varying its amplitude depending on the number of items to be remembered (Vogel & Machizawa, 2004; Jolicoeur *et. al.*, 2006). Kiss *et al.* (2008) also observed a larger SPCN amplitude when the target array was preceded by an informative cue in contrast to its amplitude to target preceded by an uninformative cue suggesting a modulatory effect of working memory processes by spatial orienting. As shown in Figure 7, it can be observed a marked SPCN component at posterior electrodes beginning at around 300 ms after target array onset. Therefore, the SPCN was analyzed in relation to the type of cue regarding the instruction (same-number or different-number cue) aiming to understand how processes involved with conflicting cues would related with maintenance of target on working memory.

Results from a repeated measures ANOVA of mean amplitude of the electrodes (P7/8, P5/6, PO3/4, PO7/8) considering laterality (contralateral and ipsilateral) and type of cue (same-number and different-number cue) revealed a significant main effect of type of cue ($F_{1,3} = 87.78$; $p=0.003$;$\eta^2=0.967$), and main effect of laterality ($F_{1,3} = 54.59$; $p=0.005$;$\eta^2=0.948$). Also an interaction effect between type of cue and laterality ($F_{1,3} = 41.98$; $p=0.007$; $\eta^2=0.933$) indicating a much larger SPCN activity when same-number cue is used to orient attention (see Figure 8). This result can be interpreted as a modulation of working memory efficiency, similarly to Kiss *et al.* (2008). It seems that using a same-number cue to orient attention reflects a more efficient maintenance of target in working memory. This result is consistent with behavioral results that revealed a faster and more accurate target response when cued by same-number cue possibly because visual information was maintained more efficiently in working memory. In contrast, having a conflict when processing the cue, observed for different-number cue, could have affected how target stimulus was maintained in working memory, thus performance when using different-number cue resulted in slower and less accurate target responses.

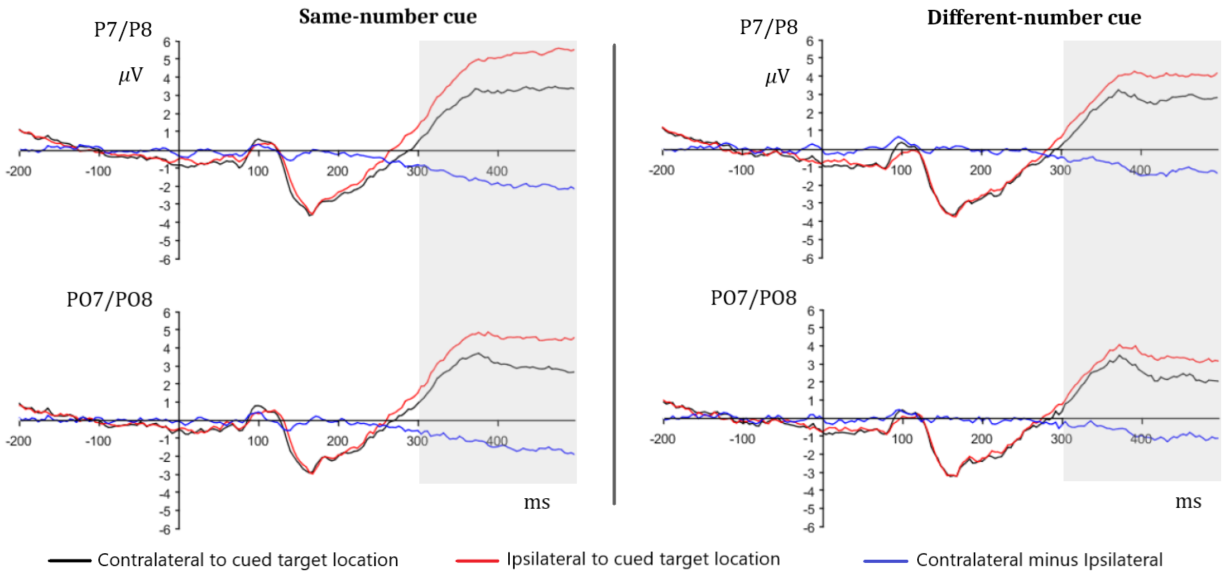

Figure 8. Grand average (N=11) contralateral (black line), ipsilateral (red lines) and contra minus ipsilateral (blue lines) waveforms time-locked to target array when cued by different-number cue (right panel) or same-number cue (left panel). Waveforms are shown from pairs of selected electrodes covering the posterior-central-anterior extent of the recordings. The shaded region shows the time window used to quantify the SPCN. The electrode montage used for the experiment is show in Figure 1 (bottom-left) with the electrodes used for all waveforms and analysis marked black.

4. General discussion

The study conducted here used a variant of the classical cueing task that consisted of using a novel cue on each trial to avoid repetitive associations between symbolic cue and target presentation at cued location that could lead to an automatized orienting of attention. A behavioral study investigated the time course of the processes involved in this voluntary orienting of attention. And an EEG study explored the ERP components elicited by processes after cue and target presentation that could be related to a truly voluntary orienting of attention.

Results from the behavioral study indicated differences in RTs and accuracy when cues were valid in contrast to invalid cues even at 250 ms SOA, not supporting the predictions that in this short SOA it would be observed a smaller or no validity effect. Therefore, these results indicate that a voluntary orienting process could happen in a time interval as short as 250 ms considering that attentional shift was triggered by novel cues on each trial. It is possible that, with a shorter SOA, validity effect would not be observed in this task. Some studies have shown validity effect, although small (around 10 ms), when using symbolic cues like colors or numbers in SOA as short as 100 ms (Olk *et al.*, 2014). This small validity effect could be related to an automatization to use the cues to orient attention from repeated associations between the cue and target location. Therefore, using an SOA of 100 ms would be best to evaluate temporal course of voluntary orienting of attention when using the task described here. However, because there is a new cue every trial, it could be difficult for subjects to use the cue in a time interval as short as 100 ms given that interpretation of cue is an important factor to be considered during time interval of SOA. This difficulty was observed in different-number cue effects. Both RTs, validity effect and accuracy were impaired when cue was different then the number presented during the instruction indicating that the conflict would impair or delay orienting of attention to target location. Further studies are necessary to clarify these questions.

Results from EEG study corroborated the behavioral data by indicating a modulation of visual working memory indexed by SPCN depending on the type of cue. Different-number cue, in comparison with components elicited by same-number cue, elicited a larger negative deflection, N2, that is related to occurrence of conflict (Larson *et al.*, 2014; Botvinick *et al.*, 2004) together with a smaller lateralized positive difference, SPCN, related to visual working memory. These results indicate that occurrence of conflict could affect orienting of attention in a manner that would interfere with accessing visual working memory to discriminate target at the cued location. Kiss *et al.* (2008) also observed modulation of SPCN when comparing processing of target with informative-cue versus uninformative-cue with a larger SPCN when using informative-cue indicating an enhancement of visual working memory with attentional shift pre-target presentation. That is, it seems that different-number cues generate a conflict when considering an attentional set preparation that is defined with presentation of a number together with a word indicating a side (the instruction previous to the cue). This conflict could be interfering with orienting of attention, as shown on behavioral results, and affecting discrimination of target which could be related to less processing of visual working memory, as correlated with a smaller SPCN. These results constitute another evidence of a relationship between attention and working memory.

EEG results also showed late positive shift-related effect, LDAP, after cue presentation instead of a late negative effect like the N2pc-like reported by Woodman *et al.* (2009). Several studies also reported the LDAP component when using central symbolic cue to orient attention (Nobre *et al.* 2000; Kiss *et al*. 2008; Hopf & Mangun, 2000). Woodman *et al.* (2009) argued that the N2pc-like effect was observed because of placeholders presence during the entire trial supporting that this component is related to shift of attention to objects instead of spatial location. Despite the fact that the present study also had placeholders it is possible that orienting in this case was to spatial locations rather to objects. Another difference was that the number of placeholders in this study was half the number of placeholders used in Woodman's study which could have interfered with the effect of placeholders found in the last study.

Congruent with this result, the N2pc component after target presentation was not observed indicating that selection of target and suppression of non-targets was not enhanced after presenting target array. Because N2pc is considered to reflect enhancement of the cortical representation of the target and/or a process that filter distracters (Luck & Hillyard, 1994b; Eimer, 1996) it is argue that a truly voluntary orienting of attention before target presentation could involve a late allocation of attention to a specific location in a way that selection and suppression processes related to post-target presentation would not be observed so clearly as in other studies (Kiss *et al.*, 2008; Woodman *et al.*, 2009). Another evidence of this hypothesis was the observation of a modest but significant contralateral positivity effect most likely to be a P1 component that supports the idea of early modulation of visual processing when target is presented in a previously attended location indicating that this effect is consistent with voluntary orienting of attention process (Mangun & Hillyard, 1991).

Because this study was partly exploratory more studies are required in order to replicate and corroborate results reported here. It would be interesting to analyze behavioral and EEG data with non-conflicting cues to see if the same effects would be observed. Also, it is indispensable to conduct an EEG experiment to properly compare ERP components between a condition with a trial-by-trial novel cue and a conditon with a automitized cue that would allow to corroborate if there are similar or different ERP components for different orienting processes. Another idea would be to use a masked display that would interrupt consolidation into working memory in order to understand how voluntary orienting of attention relates with visual short term memory for discrimination of target.

Acknowledgement: We thank Steve J. Luck for the insightful suggestions about the design of the task and analysis of data

5. Chapter III

Temporal course of endogenous orienting of attention following overlearned, instructional and free choice cues

This study was an attempt to investigate the temporal course of voluntary and automatized endogenous orienting of attention, triggered by overlearned, instructional and free choice cues. Results reported in the previous chapters indicate that minimizing cue-target associations renders endogenous orienting of attention slower (Chapter 1), possibly indicating that quicker endogenous orienting of attention involves automatized processes. In addition, when there is a conflict on using cues that differ from the established rule for orienting attention this leads to a poorer performance on the cueing task (Chapter II) which would indicate that a more voluntary process involved in endogenous orienting of attention would indeed require more time and resources for perceiving and discriminating a cued target. In the present chapter two experiments were conducted in order to compare the behavioral effects of instructional cues that allow generating cue-target associations and free choice cues that do not allow cue-target associations but only indicate that the subject may decide where to attend to. The first experiment aimed at comparing reaction times and accuracy to discriminate a target cued by arrows (overlearned cues), geometric shapes associated with a specific direction (instructional cue), and a free choice direction cue (the subject decides where to orient attention to). The goal of the second experiment was to investigate orienting of endogenous attention in a temporal order judgement task using either instructional cues or free choice cues. The general hypothesis was that free choice cues would lead to longer RTs and lower accuracy in the cueing task and longer temporal bias on the temporal order judgement task, as compared to either instructional of overlearned cues.

Temporal course of endogenous orienting of attention following overlearned, instructional and free choice cues

Jordão, E.M.A.[1]*, **Mangun, G. R**.[2] and **Xavier, G.F.**[1]
[1] Department of Physiology, Institute of Biosciences, University of São Paulo, São Paulo, Brazil
[2] Center for Mind and Brain, University of California, Davis, USA
*Corresponding author: elisa.jordao@usp.br

Abstract

Key-words: Endogenous orienting of attention; voluntary; automatized; temporal order judgement; choice cue

In a cueing task, orienting of attention is considered to be voluntary when oriented by a central symbolic cue. The stimulus presented at the cued location is detected faster indicating a sensory modulation from attentional processes. However, not all types of central cues would involve a voluntary orienting of attention like arrows that are related to an automatized orienting of attention. Also, training association of a neutral symbol with a spatial location also results in a faster orienting of attention. Therefore, it is suggested that voluntary control of attention would require a free selection of where to attend without any instruction. A choice cue would possibly allow a volitional orienting of attention, and studies indicate a distinct network activation when using this cue in comparison to instructional cues. However, there are few evidence of how this volitional orienting of attention would happen over time. The studies reported here investigated the temporal course of automatized and volitional orienting of attention using different tasks. The first one compared reaction time (RT) and accuracy to a stimulus presented at a location cued either by an arrow, instructional cue, or a choice cue. Results showed a higher RTs and lower accuracy for instructional cues compared to arrow cues, but not compared to choice cue. The second experiment investigated the temporal bias effect that instructional cues and choice cue would have on a Temporal Order Judgement task (TOJ). Results showed a similar temporal bias when attention was oriented by both types of cues, that is temporal order judgements of two stimuli were similarly impaired when attention was oriented to the location of the second stimulus. However, there was a difference of temporal bias when the time interval between cue and first stimulus varied from short to long. These results indicate that the temporal course of orienting of attention by instructional cues and choice cue are similar suggesting that there could be an influence of previous trials that facilitates current decision of where to attend. Furthermore, orienting attention by instructional cues seems to require more time when associations between cue and attentional direction are established verbally and not implicitly during task.

1. Introduction

Endogenous orienting of visual attention is considered to involve top-down processes that focus preferential processing to a specific location, thus being often considered a voluntary process. In contrast, orienting of attention can also be controlled exogenously by salient and unexpected stimuli therefore considered to be related to automatic (or bottom-up) processes (Posner & Cohen, 1984; Jonides, 1981; Muller & Rabbit, 1989). These characterizations are based in a large number of studies that use the cuing task as a model to investigate processes involved in orienting of attention (Posner, 1980; Luck & Vecera, 2002).

In a cueing task, orienting of attention is considered to occur endogenously when a central symbolic cue indicates validly the likely target location and, therefore, the individuals can use the cue to allocate their attention to it. Reaction to the target is faster when presented at an attended location and slower when presented at a non-attended location following an invalid cue, thus indicating a sensory modulation from attentional processes (Posner, 1980; Jonides, 1991; Hillyard *et al.*, 1998). Behavioral results revealed that attentional effects following symbolic cues appear after longer cue-target time intervals, as compared to attentional effects following peripheral cues (Jonides, 1981; Muller & Rabbit, 1989; Cheal & Lyon, 1991). In other words, the target is detected faster when presented at attended location if the symbolic cue and target time interval (or stimulus onset asynchrony - SOA) is about 250 ms or longer. Differently, peripheral cues reveal validity effects even at very short SOAs, e.g., 50 ms (Chica *et al.*, 2014; Castro-Barros *et al.*, 2008). These results have been interpreted departing from the assumption that because symbolic cues require interpretation by the individual, a process that involve voluntary processing and thus endogenous orienting of attention, this would be slower than the automatic processing associated with the peripheral cues that capture attention towards that location thus exogenous orienting of attention (Muller & Rabbit, 1989).

Evidence shows that certain types of symbolic cues promote faster orienting of attention. For instance, eye-gaze, arrows and numbers used as symbolic cues in a cueing task promote faster orienting of attention, sometimes equivalent to those seen after peripheral cues, even when these symbolic cues do not predict the target location (Driver *et al.*, 1999; Tipples, 2002; Ristic & Kingstone, 2012; Fisher *et al.*, 2003). These results have led to proposals that symbolic cues extensively associated with a given spatial location would automatize endogenous orienting of attention (Dodd & Wilson, 2009; Ristic & Kingstone, 2012). On the other hand, it has been shown that pre- and post-training performances in a cueing task change substantially when an association of an initially spatially neutral symbol with a spatial location is subjected to repetitive pairings, even when the trained cues do not predict the target location (Dodd & Wilson, 2009; Guzzon *et al.*, 2010).

Debates regarding the volitional aspect of symbolic cues (even when not overlearned, like eye-gaze and arrows) considers that they correspond to external instructions for the person to orient attention (Taylor *et al.*, 2008; Hopfinger *et al.*, 2010; Bengson *et al.*, 2015). The argument is that symbolic cues corresponds to an external stimulus guiding shift of attention, and this would involve other processes not related to voluntary orienting of attention such as decoding the meaning of the cue before orienting attention. Differently, a visuo-spatial attentional shift in space would be internally guided if the location is chosen by the subject rather than indicated by an external stimulus. In an attempt to evaluate this issue, Taylor *et al.* (2008) and Bengson *et al.* (2015) used a free selection alternative of orienting attention where instead of indicating a specific location the cue indicates that the subject has the freedom to choose where to orient attention to. Another approach was used by Hopfinger *et al.* (2010). These authors instructed participants to press a button when they had made the orienting choice in order to avoid any extraneous stimuli before orienting. The assumption for these studies is that a free selection of what side to attend to would involve a truly voluntary orienting of attention (or willed attention as termed by Bengson *et al.*, 2015). All three studies used functional magnetic resonance imaging (fMRI) to investigate whether specialized areas would be involved in control of internally driven orienting of attention. Overall results from these studies indicate a distinct network activation in specific regions of the medial frontal cortex and specific ERP components (frontal and central-posterior) post-choice cues that would be involved in a choice free orienting of attention in comparison to an orienting of attention by instructional cues.

Taylor *et al.* (2008) considering the possible memory effects of previous trial on decision of location to attend at current trial also investigated brain activity in a condition that required subjets to remember the immediate previous trial in order to orient attention on the current trial (memory block). That allowed a comparison between neural network activations for trials with free choice of direction of attention and trials with orienting based on memory of previous trial. Results showed that, when compared with instructional cues, choice cue trials were related to higher activation of the presupplementary eye field (pre-SEF), supplementary eye field (SEF), frontal eye field (FEF), presupplememtary motor area (pre-SMA), and anterior cingulate cortex (ACC) indicating their involvement in orienting of attention by a free selection of where to attend. However, only the activation of pre-SEF and SEF revealed to be independent of retrieving memory from past trials. Activity of ACC, pre-SMA and medial FEF seems to be also related to orienting attention using memory of previous trial indicating that these areas are more involved with remembering past actions during decision of where to attend rather than choosing per se.

Similarly, results from Bengson *et al.* (2015) also showed activation of ACC, however, differently, they also observed activation of medial frontal gyrus (MFG) and anterior insula (AI). SEF area was active for both choice trials and instruction cues. Although they did not investigate neural activity for orienting attention based on memory of previous trial, they did conduct an alpha band power analysis before choice cue presentation in another, but very similar, study (Bengson *et al.*, 2014). In this study it was observed an occipital lateralized alpha power 800 ms before cue presentation which predicted the chosen location. Although this evidence does not relate this activity with previous trial, it does reveal an anticipatory activity that could be related to previous experiences.

The study by Hopfinger *et al.* (2010) showed that FEF and superior parietal lobe (SPL) was distinctively activated when shift of attention occured by choice (without a cue) compared with instructional cues, and also observed a contralateral effect with a stronger activity on the left hemisphere of these areas. Together the evidences of these studies suggest that orienting of attention involving free choice of attended location is related to a neural network distinct from a neural network involved in orienting of attention by instructional cues. Not surprisingly some of these areas are involved in cognitive functions that would influence choice to orient attention. For example, ACC and MFG are areas related to decision making and conflict resolution (Carter & van Veen, 2007; Duncan & Owen, 2000) which would be relevant when choosing a side to attend. SPL is involved with a general initiation of attention signal (Green & McDonald, 2008). SMA and SEF seems to be related to inhibition of automatic actions initiated in response to environmental affordances (Sumner *et al.*, 2007) which could occur when task requires more control of processes. The FEF is commonly related to voluntary orienting of attention (Corbetta & Shulman, 2002), however distinctions between lateral and medial FEF could be relevant for the involvement in free selection of orienting compared to instructed orienting.

Even though brain activation showed involvement of distinct networks for orienting attention by free selection or by instruction from a symbolic cue, behavioral data did not revealed such clear disctinction. Taylor *et al.* (2008) observed a cue effect with smaller RT and higher accuracy for detection of target when cued by instructional cues when compared with detection of target cued by choice cue or when attention was divided (without any orienting). They also observed that both choice cue and instructional cues improved RT and accuracy compared to divided attention indicating that orienting did in fact occured. However, Hopfinger *et al.* (2010) and Bengson *et al.* (2015) did not observed any significant differences of reaction time (RT) and accuracy for comparison between detection of target when cued by these type of cues.

These studies using fMRI and EEG provided a relevant approach to reveal activation of distinct networks involved in endogenous orienting of attention. However, there is poor evidence regarding behavioral data, particularly on how this volitional orienting of attention would occur over time. Data on the temporal course of attentional control could extend comprehension of how processes involved in voluntary, volitional or automatized orienting of attention would differ from each other. The studies reported in this chapter aimed at investigating behavioral effects of voluntary and automatized orienting of endogenous attention, using different tasks.

The first experiment compared reaction times and accuracy to a visual target preceded by symbolic either overlearned (arrows), instructional (geometric shapes signaling - associated with - specific locations) or free choice cues, presented close to the fixation point. The goal was to gather evidence of how distinct orienting processes would reflect on RT and accuracy for discriminating a stimulus at attended location. The second experiment used a Temporal Order Judgement (TOJ) task in order to investigate the temporal biases promoted by geometric instructional cues and free choice cues on temporal biases. In the TOJ task two similar target stimuli are presented for the subject, one in the left and the other in the right, at the same excentricity. The temporal order of the stimuli as well as their temporal distance is varied. The subjects are asked to inform where the stimulus appeared first. This task allows investigation of the speed of sensory information processing, because the temporal order judgments depend on the arrival time of visual responses at a temporal comparator (Sternberg *et al.,* 1971). Differences in temporal order of two stimuli are perceived even when the arrival times of the stimuli are separated by a minimum time duration. When this time difference between the two stimuli is smaller than the minimum threshold, point of subjective simultaneity, the temporal order is not distinguished and the subject perceives that the stimuli appeared at the same time (Stelmach & Herdman, 1991). Operationally, the point of subjective simultaneity consists of equally frequent responses to the left and to the right side. Stelmach & Herdman (1991) reported experiments using TOJ associated with spatial cueing and showed that TOJ is influenced by spatial orienting of attention. That is, orienting of attention towards one side renders the subjects to judge that stimuli presented at the attended side are presented first as compared to stimuli presented at the unattended side even when both stimuli were presented simultaneously. By varying the time interval between the two stimuli in a cueing task, it was possible to measure the attentional effect. For instance, orienting of attention towards the left side renders the subjects to reach the point of subjective simultaneity even when the second stimulus was presented at the attended side about 56 ms after the first stimulus presented to the right. Similarly, orienting attention towards the right side renders the subjects to reach the point of subjective simultaneity when the second stimulus was presented at the attended side about 44 ms after the first stimulus presentation to the left.

Considering this evidence, one can speculate about what would be the effects of instructional and free choice cues, presented at varying SOAs between cues and targets, on performance of the TOJ task and point of subjective simultaneity.

2. Experiment I

As mentioned before, arrow cues are believed to trigger automatized orienting of attention (Ristic & Kingstone, 2012), choice cue would engage volitional orienting (Bengson *et al.*, 2014) and symbolic cues, devoid of any intrinsic initial directional meaning, are considered to involve voluntary orienting of attention (Olk *et al.*, 2014) even though repetitive pairing with the target could lead to some automatization.

The task used was similar to the classical cueing task but with presentation of bilateral stimuli together with the cue in order to avoid an exogenous orienting of attention interference. Either an arrow, a shape associated with a spatial location, or choice cue was presented concomitantly with two letters, one in each side of the screen. Participants had to orient attention to the instructed or the chosen location in order to discriminate the letter. That allowed to compare the time it would take to perceive, interpret a central symbol, and orient attention in order to discriminate a target. The hypothesis were that the time course for orienting attention by using an arrow, or a shape , or choice cue would be different resulting in longer RTs and lower accuracy for processes that required more resources. This hypothesis is related to the idea that choosing a side would involve a truly voluntary (or volitional) process, and would require more time when compared to an automatized orienting process by arrow cues. Further, a voluntary but potentially automatized orienting process related to shape cues associated to side could require less time than volitional orienting but more time than automatic orienting.

2.1 Material and methods

2.1.1. Participants

Nineteen undergraduate students from University of California - Davis participated in the experiment. Data of six participants were excluded because of either medical history or excess of errors (more than 30%). Therefore, data of thirteen subjects with an average age of 23 years, all right-handed, eight female were included in the analysis. Handedness was evaluated according to the Edinburgh handedness questionnaire. All subjects had normal or corrected to normal vision, and all signed an informed consent form.

2.1.2. Task

The task consisted of presenting, for 100 ms, a central cue (1º x 1º) which could be arrows or choice cue (circle shape) in two blocks; or geometric shapes associated with left (diamond) or right (square) location or choice cue (circle shape) in two other blocks. Choice cue required the participant to freely choose left or right location to orient attention. At the same time of cue presentation two letters out of four possible letters (E, F, T, L; 2º of height) were presented bilaterally and stayed on screen until a response was given or until after 2100 ms from presentation as shown in figure 1. Participants were required to respond to a 2-alternative forced choice discrimination target (discrimination of the letter showed at attended location) by pressing a mouse button. Letters and response buttons were counterbalanced within trials and subjects, respectively. After target response they had to report the side to which they had been attending. Reaction time and response to target were recorded. Stimulus was presented in a LCD display (ViewPixx) with a refresh rate of 120 Hz. Participants sat in a comfortable armchair with their eyes positioned at a distance of 80 cm from the display. Eye movements were monitored and recorded using an eye-tracker (EyeLink 1000 plus). Each participant performed four blocks of 192 trials each with 64 trials per type of cue. Order of blocks were counterbalanced between participants. For analysis purposes, blocks were divided by two with 384 trials each (128 per cue). In total participants performed 768 trials. Analysis of variance (ANOVA) for repeated measures was done using median of RT and percentage of errors considering type of cue and blocks after a boxcox transformation. The software JASP was used to conduct all analysis in the study.

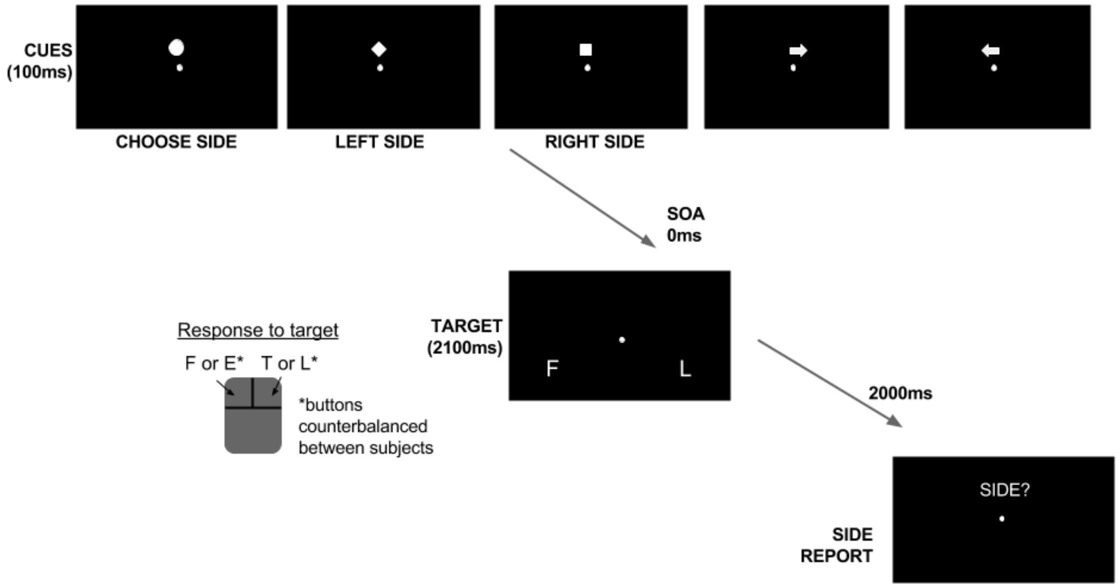

Figure 1. Task schedule showing a representation of the types of cues, target letters, type of responses and temporal course of events. Stimuli are not in scale.

2.2. Results

Trials with RTs lower than 100 ms and higher than 2000 ms were excluded from the analysis which represented 8,2% of data. Left and right side were chosen in 1643 trials and 1621 trials, respectively. Side report errors for shape and arrow cues were less than 10%. Mean RTs for correct trials and percentage of correct responses of target for each type of cue divided into two blocks are shown in Figure 2.

Descriptive data of RTs and accuracy are shown in Figure 2. RTs for orienting attention by arrow cues are smaller than RTs when orienting attention by shape cues and choice cue. A similar result seems to be present for accuracy with higher accuracy for arrow cues compared to the other cues. RTs when orienting attention with shape cues appear to be the highest in comparison to RTs from other cues, and there is a clear difference between blocks with a decrease of RTs and accuracy increasing from block 1 to block 2, and possibly a reduction of variability especially for arrow and shape cues.

No significant difference in reaction time (RT) and accuracy were found between sides (left and right) by any type of cue, therefore analysis was done with data collapsed across side. Repeated measures ANOVA for RTs including Type of Cue (arrow, shape and choice) and two Blocks of trials revealed significant main effects of Block ($F_{1,11} = 11.14$; $p=0.007$;$\eta^2=0.503$) and Type of Cue ($F_{2,22} = 5.57$; $p=0.028$;$\eta^2=0.39$), and lack of significant

Block X Type of Cue interaction effects ($F_{2,22} = 0.192$; $p=0.826$; $\eta^2=0.017$). *Post-hoc* Bonferroni's test revealed that RTs when cued by shape were significantly longer as compared to RTs for arrow cues ($p < 0.001$), thus indicating, as expected, that responses were faster when attention was oriented by arrows. RTs in trials using choice cues almost differed significantly from the corresponding score in trials using shape cues ($p = 0.068$) suggesting a tendency for slower RTs when attention is cued by shapes compared to choice cues.

Repeated measures ANOVA for accuracy revealed a similar result to the RTs analysis. Significant main effect for Block ($F_{1,11} = 8.9$; $p=0.012$; $\eta^2=0.447$), a near significant main effect for Type of Cue ($F_{2,22} = 3.11$; $p=0.065$; $\eta^2=0.22$), and lack of significant interaction between Type of Cue x Block ($F_{2,22} = 1.368$; $p=0.275$; $\eta^2=0.11$). *Post hoc* Bonferroni's test revealed that accuracy in trials using arrow cues was greater as compared to accuracy in trials using instructional cues ($p = 0.006$). Statistical analysis indicate that participants improved their performance along the task observed by the decrease of RTs and increase of accuracy for all types of cue comparing the first and second blocks. Results also show a difference of performance between arrow cues and shape cues indicating a faster and more accurate response to target when attention is oriented by arrows rather than shapes. Interestingly it was not observed a slower response to target when participants had to choose what side to attend. RT and accuracy to choice cues were intermediates of arrow and shape cues results.

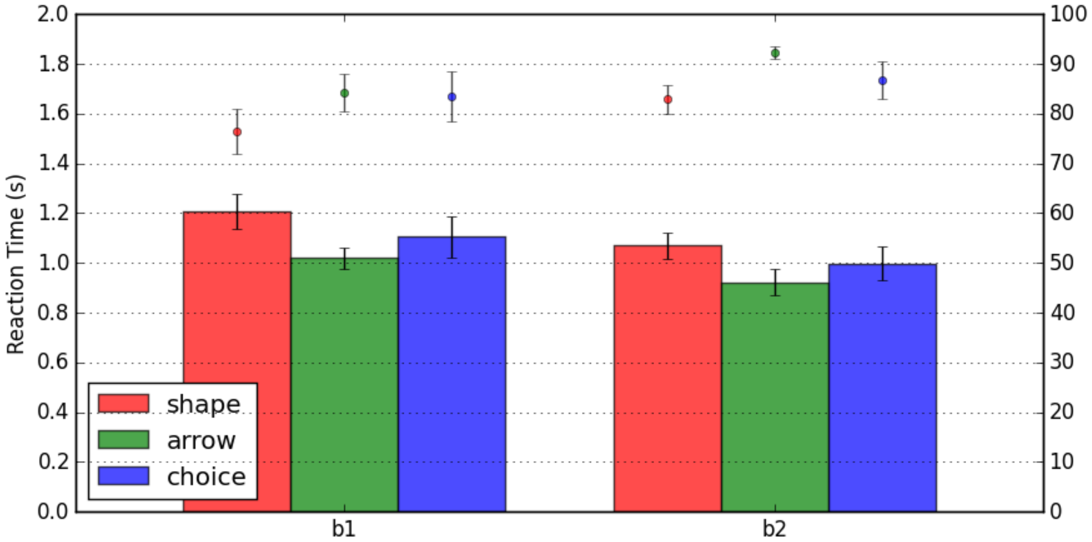

Figure 2. Mean (±s.e.m) reaction time in seconds (bars) for correct responses of target and percentage of accuracy (circles) for each type of cue (instructional, arrow and choice) as a function of two blocks of trials (b1 and b2).

2.3. Discussion

The experiment aimed at investigating the time it takes to orient attention when using different types of cues. Because it is considered that different symbolic cues and free selection of direction of attention involve distinct neural networks and processes in orienting of attention, it was hypothesized that the temporal course for each attentional control could also be distinguished. Reaction time and accuracy from discrimination of target from different symbolic cues - arrow, shape and choice cue - allowed a comparison of performance when orienting attention. Volitional orienting of attention, related to free selection of side to attend, was expected to be related to longer RTs and lower accuracy. In contrast, arrows would involve an automatic orienting of attention with a faster RT, and shape cues would also trigger faster responses, similar to arrow's RTs, after repetition of trials, perhaps on the second block.

Interestingly, results were partially different from expected. They did show a faster RT and higher accuracy for arrow cues. However, arrow cues results differed only from shape cues results, but not from choice cue indicating that orienting attention in a way free from instruction is not significantly slower than when orienting automatically. Choice cue and shape cues did not differ consistently indicating that processes involved in orienting attention by shape cues could be temporally similar to volitional processes. These results seems to put into question the idea that a volitional process is slower than an automatic process. However, it is important to consider other processes that could be related to orienting attention by freely choosing a side. In Taylor *et al.* (2008) they also compared neural activations on choice conditions with conditions where subjects had to remember previous trial (memory blocks) to orient attention so they could observe the influence of previous trial on decisions for where to attend. Some areas were activated on both conditions like the presupplementary motor area (pre-SMA) and the anterior cingulate cortex (ACC) indicating that activity in these areas could be related to remembering previous action during choosing where to attend. They also observed that RTs were faster when subjects used previous trial to orient attention compared to when they were to follow instructional cues. Furthermore, Bengson *et al.* (2014) observed an alpha lateralization at occipital cortex 800 ms before presentation of choice cue that could predict where subjects would choose to attend. They suggested that this lateralization is a pattern of ongoing brain activity that influences voluntary attention decisions. In addition, studies show that an increase of alpha power over occipital cortex ipsilateral to attended location is also related to a preparation for processing an expected stimuli at a location (Worden *et al.*, 2000). Therefore it is possible that the pre-choice cue alpha power lateralization that influence the decision to where to attend could also be influencing target discrimination performance by improving detection and discrimination of target. Therefore, it is possible that a memory of previous trials related to a pre-cue alpha lateralization could influence the decisions on choice cue, and also a preparatory activity for discrimination target by facilitating the performance of the task.

In order to investigate this hypothesis, analysis of the frequency that the current chosen attended location was the same (unswitched) or different (switched) from the attended location on the previous trial showed that subjects chose to attend the same side location as the previous trial in 55% of all choice cue trials. Although this frequency does not show that subjects were choosing a side in relation to the immediately previous trials it is possible that the overall history of previous trials would influence the choice, and perhaps would explain the lack of RT difference between arrow and choice cue. Furthermore, subjects did not go through a consistent training to associate shape cues with respective direction of attention having to rely on explicit memory only. Because the task did not give any information about correct orienting of attention (the target was bilateral and no performance feedback was given) then learning the association between shapes and direction of attention would not be possible during task, at least not as much as in a classical cueing task. Therefore there is a possibility that RTs for shape cues were higher because of difficulty in remembering the instruction, and thus to properly orient attention.

Considering these results it is possible to speculate that the processes involved in orienting of attention whether being volitional or from instructions could be much more temporally similar than previously considered.

3. Experiment II

The Temporal Order Judgement task allowed evaluation of the magnitude of the attentional bias associated with instructional and free choice cues and, therefore, the temporal course of orienting of attention in each case. This task consists of presenting two identical stimuli, one in each side of the visual field at the same excentricity, manipulating the time of appearance of each stimulus relative to the other such that one of them (either the left or the right, in a counterbalanced schedule) is presented first or both are presented simultaneously (the “delta time”, corresponds to time of stimulus presentation in the right minus the corresponding time in the left). Participants are required to inform which stimulus they perceived first, i.e., the one on the left or on the right side.

When associated with a cueing task, a cue presentation precedes, at variable SOAs, the target stimuli presentation, in order to indicate to which side participants should attend to (instructional cues), or to freely choose a side to attend to (choice cue).

In a study by Stelmach & Herdman (1991) observed that attended stimuli was perceived as occurring before unattended stimuli even when they were presented at the same time. They interpreted this result as a greater speed of transmission through the perceptual system for attended information. Further, comparing the time interval between two stimuli presentation (delta time) when participants perceived simultaneity, i.e. when responses to the left are equally frequent as those to the right, they observed a larger delta for attended side compared with delta for divided attention. That is, when attention is oriented to the opposite side to where the first stimulus is presented the temporal order became indiscriminable only when the two stimuli were presented with a temporal order difference (delta time) of about 40-50 ms. This study was conducted using peripheral cues and arrow cues which are related to reflexive and automatized orienting of attention, respectively.

The present experiment aimed at investigating, in a TOJ task, the extent of the temporal bias when orienting of attention is promoted by free choice cues as compared to instructional cues in order to evaluate the possible existence of distinct control processes. Two SOAs (stimulus onset asynchronies between the cue and the first stimulus) were employed, one short (200 ms) and the other long (700 ms) to examine the temporal course of the processes involved in orienting of attention using these types of cues.

Hypothetically, the temporal bias following free choice cues for orienting of attention, regarded as voluntary, would appear at the longer SOA but not at the shorter SOA, because in this latter SOA there would not be enough time to orient endogenous attention voluntarily. Therefore, the point of subjective simultaneity would be close to a delta time of 0 ms. In contrast, using geometric figures (instructional cues) should lead to a temporal bias following orienting of attention both at shorter and longer SOAs, because instructional cues, hypothetically, would involve endogenous automatized attention because of the repetitive pairing involving cue and location. Therefore, one expects different temporal biases at different SOAs when promoting orienting of endogenous attention using free choice and instructional cues.

3.1 Material and methods

3.1.1. Participants

Eleven graduate students from the University of São Paulo participated in the experiment. Subjects had age average of 29 years, two left-handed, and six female. Handedness was evaluated according to the Edinburgh handedness questionnaire. All subjects had normal or corrected to normal vision, and all signed an informed consent form.

3.1.2. Task

The task consisted of presenting, for 100 ms, a central cue (1º x 1º) which could be: 1) geometric shapes associated with left (diamond) or right (square) locations; or 2) a choice cue (circle shape) that required the participant to freely choose left or right location to orient attention. The time interval between the of cue onset and the onset of the first stimulus of the pair of targets, named SOA, was either 200 ms or 700 ms. The target stimuli were two circles (0.25º radius), one in the left and the other in the right, at the same excentricity, with a delta time between them varying between 8.32 and 83.2 ms (in steps of 8.32 ms – because of the refresh rate of the screen) having either the left or the right first, in a counterbalanced schedule. When the delta time was zero, both target stimuli were presented simultaneously. Both stimuli stayed on screen until a response was given, or for 4 seconds as shown in Figure 3. Participants were required to respond using a 2-alternative forced choice (left or right) indicating their perception of first stimulus location (where the first stimulus appeared) by pressing a keyboard button. After this response they had to report the side to which they had been attending. Reaction times and direction of attention were recorded. Participants were instructed to be as accurate as possible and as fast as possible. A short training session consisting of at least 48 trials was conducted so participants would learn how to perform the task. Stimuli were presented in a display (Agon) with a refresh rate of 240 Hz. Each participant performed 5 trials for each condition considering Cue (choice or shape), SOA (200 ms or 700 ms), directed Side (left or right) and Delta of time interval between stimuli (from 8.33 ms to 83.3 ms in steps of 8.33 ms) with a total of 800 trials.

Analyses involved reaction time for correct responses and the delta time of target stimuli presentation that led to the point of subjective simultaneity. The delta time was estimated by: 1) a logistic regression of correct and incorrect responses, and 2) an estimate of crossover point at which the percentage of correct responses were higher than 50% at unattended locations (see Stelmach & Herdman, 1991). Repeated measures analysis of variance (ANOVA) was used for statistical analysis of data with sphericity corrections when necessary. Four subjects were excluded due to poor performance, thus data from seven subjects were considered.

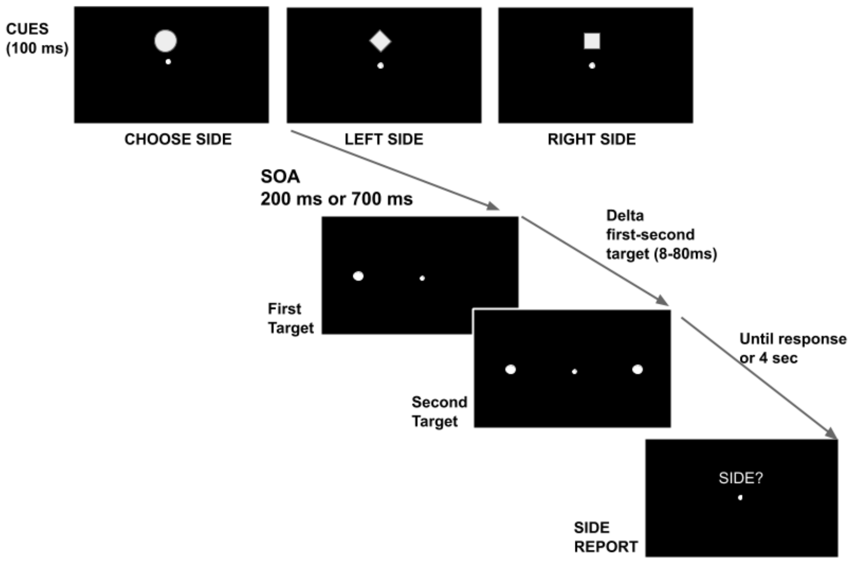

Figure 3. Task schedule showing a representation of the types of cues before presentation of the two stimuli with the first stimulus appearing on the left, and the response to temporal order and response to which side attention was oriented at the end of the trial.

3.2. Results

Descriptive analysis of data shows that there was no preference for side location on choice condition (52% of responses to right side) and less than 3% of incorrect response to direction of attention when using instructional cues. The percentage of correct responses to the temporal order of stimuli corresponded to 69%; data analysis of median reaction times included only trials in which the response was correct.

Figure 4 shows the percentage of responses indicating perception of the first target stimulus either at the left or at the right sides, as a function of SOAs (200 ms at the 4 top panels and 700 ms at the 4 bottom panels), when using either (1) free choice cues (a circle) informing that the subjects could decide to oriented attention towards the left (left panels) or the right (right panels) sides at will, or (2) instructional cues indicating that attention should be oriented towards the left (left panels, diamond-shape cue) or the right (right panels, square-shape cue), as a function of the Delta time in frames (time for presentation of left "minus" time for presentation of the right stimulus) with negative values corresponding to first stimulus presented on the left side and positive values corresponding to first stimulus on the right side.

Statistical analyses used an estimation of delta time calculated from crossover points, and from a logistic regression. Both estimations considered type of cue and corresponding side (either chosen or instructed depending on the cue), SOA and side of the first stimulus presentation. These estimated delta time thresholds were analyzed separately including cue type (choice-left, choice-right, shape-left or shape-right), SOA (200 or 700 ms) and first stimulus presentation (right or left) repeated measures ANOVA. Similar results were observed for both delta times calculated from crossover points and delta times obtained from logistic regression, however there were slight differences (see below).

ANOVA revealed a significant main effect for SOA for delta times calculated from crossover points ($F_{1,6} = 6.05$; $p=0.049$; $\eta^2_p =0.5$) but not for delta times obtained from logistic regression ($F_{1,6} = 3.59$; $p=0.131$; $\eta^2_p =0.47$). Differently, ANOVA revealed lack of significant main effect of cue type for both delta times calculated from crossover points ($F_{3,18} = 0.81$; $p=0.5$; $\eta^2_p =0.119$) and delta times obtained from logistic regression ($F_{3,18} = 0.826$; $p=0.5$; $\eta^2_p =0.171$).

ANOVA involving delta times calculated from crossover points and delta times obtained from logistic regression revealed significant interaction effect for Cue type and Side of the first stimulus ($F_{1.19, 7.17} = 6.127$; $p = 0.038$; $\eta^2_p = 0.5$; $\varepsilon = 0.39$), and ($F_{3,12} = 3.95$; $p=0.036$; $\eta^2_p =0.49$, respectively). No other effects were revealed.

As Figure 4 shows in most of conditions, results clearly show a temporal bias of the point of subjective simultaneity (50%) towards the side where the subjects oriented attention to. In other words, when subjects oriented attention to a given side, this increased their likelihood of perceiving the first target stimulus at that side, even when the first stimulus appeared in the opposite side, particularly at smaller deltas. Subjects' frequencies of responses as having detected the first stimulus either at the left or at the right increase substantially when delta time increases. However, the slope of responses frequency as a function of delta time differs depending on the direction of attention and SOA. At the extremes of delta times (both negative and positive) there were higher frequencies of correct responses, because the subjects are capable of detecting the first stimulus having no doubts even when attention was oriented towards the opposite side. However, responses tend to be equally frequent at smaller delta times, particularly when first stimuli is presented at unattended locations. The shift of frequencies of responses (from left to right or from right to left), i.e. the crossover point, occurs when the delta time allows the perception of correct temporal order. When attention is oriented away from first stimulus location a longer delta time is required for this shift to happen.

Results also show that at a short time interval between the cue and the first stimulus (200 ms SOA) (Figure 4, four top panels) proper perception of the temporal order when attention is oriented towards the opposite side relative to that of the first stimulus requires a delta time of around 75 ms (corresponding to about 18 frames). In contrast, with a longer SOA (700 ms), the delta time is much shorter at the corresponding condition, i.e., about approximately 58 ms (corresponding to about 14 frames) (Figure 4, four bottom panels).

The type of cue (either free choice or instructional shape) seems to produce distinct delta times for the point of subjective simultaneity at the SOA 700 ms (Figure 4, four bottom panels); this effect seems to be stronger when attention is oriented towards the right side. That is, choosing to attend to the left seems to require longer delta times (about 14 frames) to increase the percentage of correct responses as compared to choosing to orient towards the right (about 8 frames), as if orienting voluntary attention towards the right side was a quicker process.

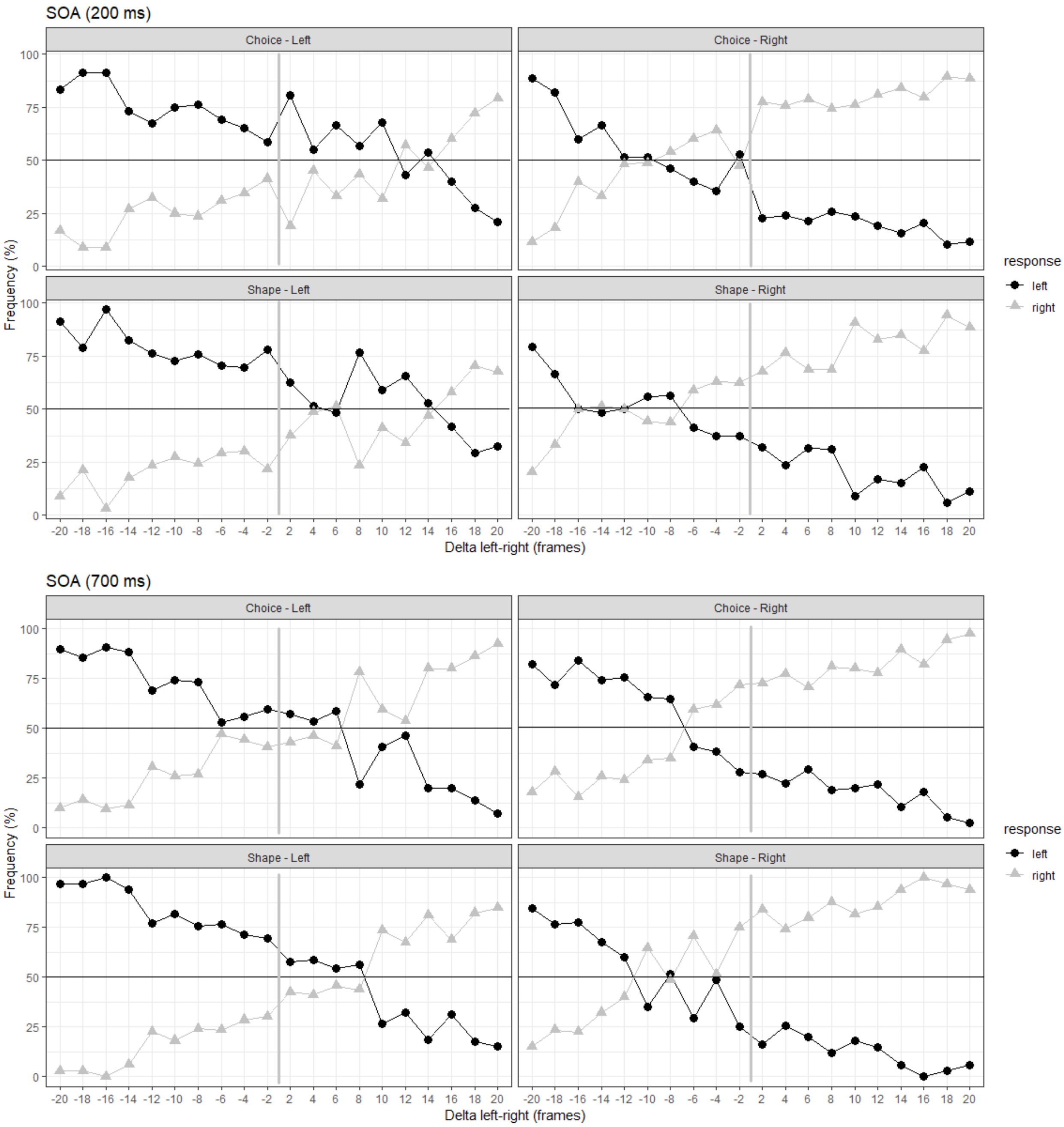

Figure 4. Frequency of left or right responses for each time difference between stimuli – delta in frames - calculated from the time of presentation of left stimuli minus the time of presentation of right stimuli (negative values means first stimulus on the left, and positive values means first stimulus on the right). Responses are shown for each SOA (200 or 700 ms) of the two types of cues (choice or shape) when attention is directed for each side.

In summary, these results show that the crossover points thresholds are different at distinct SOAs with smaller thresholds at longer SOA. This indicates that subjects can perceive temporal order with a shorter delta time, i.e. better perception, when longer SOAs between cue and first stimuli are available. The significant interaction effect involving Cue type and First stimulus side were expected and shows that orienting attention to a given side bias temporal order perception by speeding detection when the first stimulus is presented at the attended location and delaying detection when first stimuli is presented at the unattended location.

In order to simplify analyses involving RTs as a function of delta times, data were collapsed into short delta times (from 2 to 10 frames) and long delta times (from 12 to 20 frames). Then, analyses involving RT included the median score for each subject in each experimental condition, including Type of Cue (choice-left, choice-right, shape-left and shape-right), SOA (200 and 700 ms) and Delta time (short or long) as explained above. ANOVA revealed a significant main effect of SOA ($F_{1,6}$ = 10.51; p=0.018; η^2_p =0.64) and a close to significant main effect for Delta time ($F_{1,6}$ = 4.92; p=0.068; η^2_p =0.45), indicating, as expected, that smaller RTs are observed in association with longer time intervals between cue and the first target stimulus. There were no significant effects of main type of Cue ($F_{3,18}$ = 0.143; p=0.143; η^2_p =0.25) or interactions with other variables. These results are compatible with the results involving delta time thresholds presented above. In this context, it is important to note that subjects were instructed to prioritize accuracy over reaction time.

3.3. Discussion

In the TOJ task, correct temporal order judgments depend on the presentation of stimuli to be evaluated using a minimum temporal separation between them. If this duration is too short, there is a perception of simultaneity. It is well known that this minimum duration may vary when attention is directed to the opposite side relative to that where the first stimulus is presented. That is, orienting attention can bias temporally the minimum duration so that simultaneity is perceived with a longer time interval between stimuli presentation compared to divided attention’s minimum duration.

Stelmach & Herdman (1991) showed that this temporal bias from orienting attention increased the minimum duration of about 56 ms for attended left, and 44 ms for attended right using peripheral and arrow cues. This temporal bias is considered to occur because attention would improve perception and speed of detection of the attended stimulus. In addition, it would inhibit processing of the unattended stimulus presented at the opposite side. Therefore, in order to perceive first the unattended stimulus it would require it to be presented about 40 ms in advance relative to the attended stimulus.

The experiment reported here aimed at investigating whether the temporal bias for the point of subjective simultaneity differs when attention is oriented either by a choice cue or by an instructional cue, using both short and longer SOAs. Because a free choice cue is believed to engage endogenous voluntary attention, one did not expect to observe attentional effects at a short SOA; therefore, temporal bias should be close to 0 ms, i.e., similar to when attention is divided. Furthermore, if temporal judgements depend on the speed at which information is processed, it seems plausible that faster processes involved in orienting attention could influence temporal bias by increasing the required delta time for unattended stimulus to be perceived first.

Experiment I revealed that endogenous automatic orienting of attention by arrow cues promotes faster reaction times and higher accuracies of the attended location as indicated by the arrow as compared to instructional shape or free choice cues.

Although no consistent differences between type of cues were observed, there was a clear effect of orienting attention either by choosing where to attend or by instructions on the minimum duration for temporal order to be perceived. Results showed that in order to perceive the temporal order when first stimulus is unattended a larger temporal bias of about 75 ms when attention was oriented by choice cue and shape cues at a short SOA of 200 ms (100 ms of cue presentation). In contrast, at 700 ms SOA, orienting attention by using these cues resulted in a smaller temporal bias that varied from 42 ms to 58 ms. These results are congruent with those reported by Stelmach & Herdman (1991). However, the hypothesis that a shorter temporal bias would be observed for choice cues was not supported by the results. On the contrary, there was a larger temporal bias at a shorter SOA compared to the temporal bias at longer SOA, and no type of cue effect. Therefore, this indicates that in the present experimental conditions a 200 ms SOA is sufficient for orienting of attention to occur when direction of attention is instructed by cues similarly to when direction is a choice to be made. Even though this result was not expected, it does seem to be congruent with the results found of Experiment I where it was observed that the RTs related to orienting of attention by choice cue did not differed from RT from orienting of attention by arrow cues. It seems that deciding where to attend and directing attention to it could occur in a rapid and efficient way that would take no longer than 200 ms.

Regarding to the shorter temporal biases at the SOA of 700 ms realtive to the SOA of 200 ms, it could be reasoned that if 200 ms is sufficient for orienting of attention to occur, then the process of orienting attention would require only part of the duration at the longer SOA. Therefore, after attention is allocated to a side the effort of sustaining attention at this location is required for the remaining duration of the SOA.

Consistently with results from Experiment I not showing a significant difference of RTs and accuracy when using free choice cues and instructional shape cues, results from Experiment II also did not show different temporal biases when using these cues. These results indicate a similarity in the temporal course of the processes involved in orienting of attention when triggered by different cues even if these processes are involved in activation of distinct neural networks as reported by other studies (e.g., Taylor et al., 2008; Hopfinger et al., 2010; Bengson et al., 2015).

As speculated before, it is possible that previous trials would influence the decision on free choice cue trials in a way that would facilitate the process involving where to attend to. The frequency that the chosen attended location was the same or different than the attended location on the previous trial showed that subjects chose to attend at the same side as in the previous trials in 68% of all choice cue trials. This analysis shows that there was a tendency to choose a location based on the attended location on the previous trial. Therefore, this could have speeded the decision process. Perhaps, if more training were employed in order to facilitate the association between instructional shape cues and the location for orienting attention the difference of temporal course involved in different types of cues would be observed. Further studies employing training for arrow cues, instructional shape cues and free choice cues could add to this hypothesis.

4. General discussion

Orienting of attention is believed to engage distinct dissociable processes. When using symbolic cues, supposedly one engages endogenous attention that could be either voluntary when free choice cues are employed, or automatized when instructional cues, like geometric figures (shapes) indicate the likely target location, thus allowing the acquisition of a cue-target association. In addition, there are symbolic directional (culturally established) cues, including arrows and eye-gazing, that would have been overlearned and thus engage endogenous automatized orienting of attention.

In general, results of the Experiments I and II revealed similar temporal courses for orienting of attention. Experiment I showed that RTs were substantially shorter when orienting of attention was promoted by arrow cues as compared to instructional shape and free choice cues. Even though these later (instructional and free choice cues) did not differ significantly among each other, their comparison almost reach statistical difference ($p = 0.065$), being reaction times when using free choice cues longer as compared to instructional shape cues. Congruently, accuracy was greater when using arrow cues as compared to when using either instructional shape or free choice cues. These figures provide support to the hypothesis that the time course of orienting attention depends on the type of cue possibly indicating distinct processes of orienting attention. However, one have to be cautious with this conclusion because the positive results in this experiment were close to significant but not significant.

Experiment II, employing instructional shape cues and free choice cues in a TOJ task, revealed expected temporal biases that were influenced by orienting attention to the opposite side relative to that of the first stimulus presentation. The temporal bias (crossover point) was of about 75 ms at the SOA of 200 ms, and of about 58 ms at the SOA of 700 ms, thus indicating that this task provides an adequate model for investigating endogenous orienting of attention effects to these types of cues.

Differences in RTs and accuracy between shape cues and arrow cues, but not choice cue, indicate that processes involved in orienting attention by instructional cues required a longer times. Normally, instructional cues require a learning process so that the symbolic cue, in this case geometric shapes, can be associated with its respective direction of attention. Training for this association was not conducted in Experiment I and only a short training in Experiment II (around 50 trials). Furthermore, the tasks' designs did not allow implicit learning of associations during the task because there was not a probabilistic relationship between cue and target. It is important to note that in TOJ task there is not a target per se since the goal is to judge which of two stimuli appeared first independently of attention direction. Therefore, perhaps more time was required for accessing meaning of the shape cue in order to orient attention properly. Working memory (WM) would have an important role in this task since it requires a temporary storage of visuospatial information and a complex manipulation of it (Baddeley, 2012). In addition, top-down control of attention seems to be related to prefrontal cortex (PFC) representations from a wide range of learned associations like the one to orient attention along a task (Miller & Cohen, 2001). Interestingly, there are eletrophysiological evidences showing preferred activity of lateral prefrontal neurons related with associations between a visual cue and an instructed directional saccade (Asaad *et al.*, 1998), and similar associations are also decode in FEF (Bichot *et al.*, 1996). Further, it is considered that the dorso-lateral PFC participates in the neural mechanisms of WM responsible for maintaining and processing information necessary for performing a task (Funahashi, 2006). Based in the WM model it could be that during the tasks reported here the explicit associations between shape cues and direction of attention is maintained in the episodic buffer in order to be used when necessary, which could involve a slower processing of information especially because shape cues and choice cue were presented in a mixed block condition. Therefore, there was an unpredictability of what type of cue was going to be presented on the current trial. Apparently, information about arrow cues were easily handled probably because of the overlearned association between arrows and direction of attention meaning, and thus facilitating the control of orienting of attention and response to stimuli.

In relation to the results regarding choice cue it is possible that the lack of difference between time courses for a volitional process and for processes involved with shape cues or arrow cues could be related to an effect of previous trials on decision to choose a side. As already mentioned, studies by Taylor *et al.* (2008) and Bengson *et al.* (2014) demonstrate that some neural mechanisms involved in free selection of direction of attention are also involved in retrieving memory from previous trials, and that there is a preparatory alpha lateralization at occipital region that might influence decision on choice cue. Those evidence seems to be congruent with studies that show a sequence effect on spatial cueing tasks (Jongen & Smulders, 2006; Qian *et al.*, 2012). These studies observed that a cueing effect (i.e. validity effect) was larger after a valid trial than after an invalid trial indicating that experience from previous trial does indeed influence performance on current trial. Therefore, it seems plausible to consider that something similar to the sequence effect could influence decisions when choice cue is presented, even if subjects were instructed not to follow a marked strategy and to try counterbalancing choices. In an attempt to answer the question regarding the effect of previous trial on decision of where to attend, results showed that subjects chose to attend to the same location as the previous attended location on 55% and 68% of choice trials for Experient I and Experiment II, respectively. Although not conclusive these results indicate that there is a tendency to choose the same location from the previous trial location supporting the idea that there is an influence of previous trials on decisions for choice cue. A study controlling for sequence effect on choice cue could elucidate these hypothesis. Further studies are necessary to understand better the lack of temporal differences observed between shape cues and choice cue, and the differences of temporal biases at different SOAs in a TOJ task.

6. General discussion

Orienting of visual attention is considered to occur in two distinct ways, automatically (exogenously) or voluntarily (endogenously) (Posner & Cohen, 1984; Muller & Rabitt, 1989; Jonides, 1981). However, different studies have shown that endogenous orienting of attention not necessarily engages voluntary processes, possibly involving “automatic” processes (Friesen & Kingstone, 1998; Ristic et al., 2002; Tipples, 2002; Ristic & Kingstone, 2012; Fisher et al., 2003; Olk et al. 2014).

In order to distinguish the exogenous automatic (or reflexive) capture of attention (mostly by peripheral non-predictive stimuli) from the endogenous “automatic” orienting of attention, we have employed endogenous “automatized” orienting of attention. The reason for proposing this use relates to the fact that most of studies referring to this kind of orienting of attention employed either directional symbolic cues overlearned culturally (like arrows or eye-gazing figures) presented close to the fixation point (Friesen & Kingstone, 1998; Ristic et al., 2002; Tipples, 2002; Ristic & Kingstone, 2012), or symbolic cues, also presented close to the fixation point, that were consistently paired with presentation of the target stimulus in a given location (Guzzon et al., 2010; Dodd & Wilson, 2009). Only a few studies considered the possibility that endogenous automatized orienting of attention could arise from repetitive associations of stimuli occurring in classical cueing task despite the concern of researchers when using visual search tasks (see Awh et al., 2012; Theeweus, 2018).

The main purpose of the present experiments was to gather behavioral and electrophysiological evidence for a possible dissociation between endogenous automatized and endogenous voluntary orienting of attention. If in fact there are two distinct processes for endogenous orienting of attention, it should be possible to reveal them using distinct behavioral tasks. This demonstration, if feasible, would represent a strong argument in favor of the dissociation.

It is believed that exogenous automatic control is faster and effortless; therefore, cues engaging this process would promote validity effects even at short SOAs. In contrast, endogenous voluntary orienting of attention would be controlled and require effort; therefore, it would not be seen at short SOAs, but only at longer SOAs. However, as the subjects establish an association bewteen cue and target location along the task performance, an automatizing endogenous orienting of attention could occur, thus leading to the occurrence of validity effects even at short SOAs. The experiments included in this study were designed departing from these assumptions. Therefore, in order to reveal a truly endogenous voluntary orienting of attention then the cueing task should avoid automatization of the association between the cue and the target location.

Two variants of the classical cueing task were designed (Chapters I and II). In Chapter I, a stimulus was inserted between cue and target presentation in order to minimize repetitive contiguous presentation of predictive cue and target at cued location, and thus avoid strengthening of association. In Chapter II, a novel symbolic cue was presented on each trial in order to avoid association between one symbol and a spatial location. For this, a rule had to be established previously to cue presentation which could be congruent to the presented rule (same-number cue) or incongruent (different-number cue).In Chapter III, a variant of a cueing task, the subjects were instructed to freely choose the side where they would orient attention to without knowing where the target stimulus would appear. Therefore, the task would not be automatized, thus engaging a truly endogenous voluntary control of attention.

The overall result showed that although there is an interference on performance when less time is available for effortful orienting of attention, only a time interval as short as 150 ms did significantly impact orienting performance in one experiment (Chapter I). The results seem to indicate that the temporal course for voluntary orienting of attention in these tasks is shorter than what was assumed, i.e. around 300 ms, and that endogenous orienting of attention involving different processes seems to show similar time courses when comparing orienting of attention triggered by a symbolic cue associated with a spatial location or by freely choosing where to attend. Furthermore, it seems to occur a facilitation of endogenous orienting of attention even when it demands more cognitive resources, possibly related with a well established contingencies of the task and its many repetitions allowing learning mechanisms to reinforce associations and facilitate performance.

The evidences reported from the three studies will be discussed within a framework structured around the idea that the distinctions of an automatized and voluntary endogenous orienting of attention described before are related to the strength of the association between a visual stimulus (cue) and a location in space (left or right) that vary in a continuum through different learning mechanisms. This association would be involved in the formation of an attentional set which refers to the bias to attend specific features and responses that are relevant for performance of a task (Tait & Brown, 2010). Therefore, the strengthening of the association is considered to occur in a recurrent feedback (Eimer, 2014). Information about the association is activated and manipulated in order to be used as an attentional set that bias selection of features and responses relevant for behavior, if the behavior is successful then the associations, hence the attentional set, is reinforced facilitating the use of information in the following events. These processes will be further discussed considering the components of working memory (WM) and its link to long-term memory (LTM).

The first study (Chapter I) reported here used a variant of the classical cueing task (Posner, 1980) to investigate the temporal course of orienting of attention when repetitive sequential presentation of central symbolic cue and target location is avoided. The insertion of a stimulus between cue and target, called anchor, resulted in higher reaction time (RT) and errors to target when participants had to report anchor in comparison to results when participants did not have to report it. Furthermore, results from the group with a predictive condition (64% of valid trials) that had to report anchor showed a lack of validity effect for the shortest SOA (150 ms). Together these results show that having to report anchor interfered in orienting of attention that resulted in slower and poorer detection of target. Therefore, the lack of validity effect at 150 ms SOA for the group that reported anchor it is an indication of the involvement of a slower and effortful control in orienting of attention in contrast with a more effortless and fast attentional orienting occuring in the group that did not report anchor and did show validity effect at 150 ms SOA. To complement, results from Experiment II showed a lack of validity effect at 50 ms SOA considering the time interval between anchor and target even without requirements to report anchor. This evidence supports that anchor did interfered with orienting of attention, and could be regarded as a signal marker to when shift of attention occurs.

It could be reasoned that for endogenous orienting of attention to occur in this task the association of symbolic cues with a direction of attention on space was learned explicitly by verbal instruction, and later was maintained by implicit learning from repetitive associations of cue and target at attended location for the groups in a predictive condition even with the anchor. The active representation of the association can be used to form an attentional set that bias selection of features and responses relevant for performance of the task. The maintenance and utilization of information such as the attentional set to perform a task seems to depend on visual working memory (Woodman & Luck, 2007). Therefore, it is possible that the interference observed on orienting attention when anchor needed to be reported could be due to the competition of information manipulation on working memory since the type of anchor was relevant and had to be retrieved after response to target. In contrast, when anchor is not required to be reported then there is no competition in working memory which would facilitate manipulation and reinforcement of associations between cues and direction on space across trials resulting in faster processing, responses and larger cueing effects. Therefore, the need for working memory resources would be related to a more voluntary control of attention. This could explain how the group with predictive condition and no anchor report showed validity effect at the shortest SOA, but that was not observed in the group that had to report anchor. A question that might be worth investigating is whether and how the anchor interfere with orienting of attention when subjects are trained to associate cue and location of target before performing the cueing task with the anchor. If interference of anchor on performance is the same as observed here then it would indicate that to perform the task representations of cue and direction of attention still require working memory resources independently of its association strength. However, if anchor interference is different then it would suggest that an already learned association do not require working memory resources to perform a cueing task which would support the idea that a more automatized control of attention does not require WM resources.

A study already answered partially this question when showed that increased WM load interfered, although moderately, in endogenous orienting of attention when cues were arrows (Vossen *et al.*, 2016). The study used a dual task which consisted of given a sequence of five digits (randomized order for high WM load and ascending order for low WM load) to subjects that they had to remember after performing a cueing task. Results showed that a high WM load compared to low WM load reduced sensitivity of target detection. They also reported that EEG results showed a delay for the alpha band power lateralization at occipital region and for the anterior ERP component, ADAN, when WM load was high. This study indicates that orienting of attention involves WM capacity even for overlearned cues related with an automatized control. It is important to note that in this study the information to be retrieved after orienting of attention was auditory, and was given before presentation of the cue. It would be interesting to know if using this task design would render similar interference as the one observed in the variant of cueing task reported here because it would remove the possible confounds of having the interference of a visual stimulus between cue and target presentation.

On the second chapter, a behavioral and an EEG studies used another variant of the classical cueing task, which consisted of instructing, in a trial-by-trial manner, a rule that would be used to direct attention. A three-digit number together with the word “RIGHT” or “LEFT” was given as a rule that set how the cue would direct attention. The cue could be the same number, which would direct attention to the side corresponding with the word, or could be a different number, which would indicate the opposite side of the word. The target was a C-shape with the gap oriented up or down, which had to be discriminated for response. Behavioral studies showed a consistent validity effect even at a short SOA (250 ms), and a consistent tendency for higher RTs and lower accuracy when cue was a different number indicating that using a different number from the rule interfered with orienting attention, but not to the point of extinguishing validity effect. Furthermore, for the EEG results it was observed at 500 ms post-cue a positivity contralateral to the cued location, which could be similar to the LDAP component related with voluntary shifts of attention. Although no post-cue lateralized ERP component was observed at anterior electrodes, recordings in those electrodes did show a modulation of an ERP component, possibly the N2 component, at around 250 ms corresponding to a negativity enhancement related to different number cues indicating a conflict process when this type of cue is presented. Also, a lower modulatory activity of the sustained posterior contralateral negativity (SPCN) was observed after target presentation cued by different number in comparison to the modulatory activity of SPCN after target was cued by same number cue. This component would indicate activation of visual representation on WM, thus targets cued by different number cue seems to have a lower modulatory activity of its representation on WM which would agree with lower accuracy for discriminating it.

These results indicate that a voluntary orienting of attention in a trial-by-trial manner can occur in a time interval as short as 250 ms. It is possible that the rule, which is presented before the cue, is represented visually as the attentional set (Tait & Brown, 2010) that will bias selection of features and responses relevant for performance of the task. Therefore, there would be a sensory and response preparation for what would be presented visually (the cue number) and its associated direction during each trial that could facilitate performance even in a trial-by-trial basis. Furthermore, it seems that the impairment of task performance when cue number is different from the rule could be interpreted as a conflict of sensory information processing to guide orienting of attention. Because the cue number could be either congruent (same number) or incongruent (different number) with the attentional set formed by the previous rule, a decision would be necessary in order to orient attention properly. If a congruent cue is given then the decision is fast because there is a preparatory activity, and orienting occurs undisturbedly. However, if the cue is incongruent then the preparatory activity needs to be inhibited for a decision to be made in opposition to rule. Orienting in this case would take longer, which could interfere with performance. This incongruence seems to be related to conflict shown by the negative deflection of N2 component observed on anterior electrodes when the cue number was different compared to when was the same from the rule. Therefore, as suggested, the attentional set established by the rule would need to be stored and manipulated so that the cue can be interpreted and a decision can be made for orienting of attention to occur. Some studies argue that the attentional set is an integrated part of visual WM despite being functionally different of a representation memory activation because it would involve the control of selection bias based on current task relevance (Olivers & Eimer, 2011). The prefrontal cortex (PFC) is often related to attentional control functions and probably has a relevant role in the underlying neural mechanisms responsible for deciding which sensory representation is prioritized, especially because PFC exhibits the necessary feedback connections with sensory systems that would allow implementation and sustain biases signals (Miller & Cohen, 2001). Therefore, the observed modulation of the anterior N2 component related with conflict when cue was different from the rule number is congruent with the PFC involvement on selection bias.

In the study of Chapter II the frequency of valid trials was 75% (behavioral study) or 90% (EEG study), which also explain the consistent validity effect observed at all SOAs. When behavior is successful, which in this task would be using the rule information in order to orient attention properly to the location where the target is presented, signals are reinforced and enhance the corresponding pattern of activity for that behavior. Therefore it might be interesting to know whether there is a different interference of incongruent cues if frequency of valid trials is 50%. Perhaps more uncertainty related to the contingencies of the task would cause an overall lack of validity effect, or possibly a poorer performance for different number cue.

On the third study (Chapter III) two different tasks were used to investigate the speed of processing stimuli when attention is directed to it by different types of cues. In Experiment I, the task used was similar to the classical cueing task, but with a bilateral stimuli (letters) presented at the same time as the cue. The target was the letter on the correct location indicated by the cue and had to be discriminated. The cues used on this task were arrow cues, shape cues associated with direction of attention, and a choice cue which allowed a free selection of direction of attention. Results showed that performance of the task differed significantly between arrow cues and shape cues but not with choice cue indicating a higher RT and lower accuracy for attended stimuli after presentation of shape cues. This result suggests that more effort and processing time were required for orienting attention when using shape cues. The lack of difference between the speed of processing stimuli when shift of attention is triggered by shape cues and by choice cue was also observed in Experiment II. TOJ task was employed in Experiment II with attention being directed by shape cues or by choice cue at short SOA (200 ms) or long SOA (700 ms). It was observed that when the first stimulus was unattended there was a larger temporal bias (75 ms) for correct judgements of temporal order at the short SOA compared to the temporal bias (58 ms) at the long SOA. However, no difference was found between temporal biases when attention was directed by shape cues or choice cue. These results show that shifts of attention occurred even with a

200 ms SOA independently of type of cue indicating similar temporal courses of orienting of attention when controlled by external cues associated with a direction (shapes) or controlled by the subject's decision (choice).

The interpretation for these results also rely on the idea of an attentional set formed during task to bias decision on how to use cues to orient attention. Formation of the attentional set for shape cues would be similar to the one on the task reported on Chapter I (position of a small circle at fixation point indicate direction of attention). Therefore, representation of the association between shape cues with the respective direction of attention on space would first be learned explicitly and, along the task, learning would become more implicit facilitating cue information processing and decision for proper behavior. However, both tasks reported on Chapter III does not allow for implicit learning during task for shape cues because there is not a probabilistic relationship between cues and stimuli presented after cue, which are bilateral. That is, the presentation of a shape cue, and thus its instruction of direction of attention, is not reinforced by the presentation of a stimulus at the instructed location. Therefore, this lack of reinforcement by implicit learning would delay the strengthening of attentional set, and thus facilitation of orienting attention by shape cues. In this case, it seems that subjects have to rely heavily on verbal instruction given at the beginning, and sometimes again at the middle, of the task. In contrast, arrow cues, as mentioned before, are overlearned spatial cues which already possesses a robust representation resulting in a fast construction of an attentional set to perform the task, which could result in faster processing of stimuli to orient attention and to respond to attended stimulus. Apparently, for the choice cue the attentional set seems to depend on previous trials. That is, it could be possible that a strategy based on previous experience influence how current decision is made about where to orient attention. Contrary to the expectation that, because it would involve a slower, more effortful and complex processing, a choice cue would be related to slower RTs, lower accuracy and smaller temporal bias on TOJ task at short SOA which was not observed in the results. Similar to shape cues conditions, reinforcement of behavior for choice cue is not dependent on cue-target relationships, therefore representation for selection bias would be influenced by other contingencies such as the previous attention allocation that would facilitate performance of the task. For Keller (2008) volition is normally related to conscious effort influenced by extrinsic requirements and past experiences, thus selective attention is considered a necessary process for volition to happen. In this context, the act of choosing where to attend depends itself from a selection of what information is prioritized and what is ignored in order for this decision to happen.

Other studies need to be conducted in order to understand better the effects observed when using different types of cues. The effect of a shorter SOA in TOJ task should be investigated using arrow cues, shape cues and choice cue in order to further elucidate the similarities or differences of temporal courses for these type of cues and their related processes. In addition, it would be interesting to control for previous trials effect on choice cue, and control for robustness of associations between shape cues and their correspondent direction of attention.

Results reported here did not corroborated consistently that a voluntary orienting of attention would present a distinct temporal course from a more automatized endogenous orienting of attention. However, it did show that task performance is impaired when there is a conflict or interference in processing the information about where to attend. Therefore, the discussion of results takes into account some models that seem to fit well within the idea that the distinction on controlled attention depends on signal strength obtained from learning mechanisms.

The well-known three-component working memory model (Baddeley & Hitch, 1974) that was latter updated to a four-component model (Baddeley, 2000) allows a broad understanding of how information is temporarily stored and manipulated during performance of cognitive tasks. In short, WM model consider a central executive (CE) responsible for attentional control that comprises a number of executive functions. This CE is supported by two systems which are called slave systems that hold temporarily visuospatial information (sketchpad), and verbal and acoustic information (phonological loop). The episodic buffer, which was the fourth added component, functions as a storage of multi-dimensional codes providing a temporary interface between the two slave systems and long term memory (LTM). It is also controlled by the CE which can influence what information is stored by attending to information from any given source. The necessity to include such system in the model came from evidence showing a very significant increase of memory span when meaning was added to phonological information. That is, when presented words made up a sentence the memory span for those words was of 15, but when they were unrelated words the memory span dropped to only 5. This, and other evidence, showed that there is an interface between the phonological loop and a semantic system which could also be true for the visuospatial sketchpad. Therefore, the episodic buffer would be responsible for holding a temporary activation of a multidimensional representation and allowing its manipulation if necessary for the current task, thus linking WM to perception and LTM (Baddeley, 2012). Also, the buffer is episodic because it holds information that is integrated across space and potentially extended across time as episodes.

The CE appears to be the most complex component of WM which would take on many functions related to focus of attention and decision making related to tasks that require dividing attention between stimuli streams or switching between tasks (Baddeley, 2012). Further, CE would also be able to retrieve information from the episodic buffer in the form of conscious awareness, a function that depends on attention. Therefore, the theoretical hypothesis considered here is that the attentional set mentioned before would be related to the CE. That is, the attentional set refers to the bias to prioritize features and responses that are relevant for behavior, and this function would be related to the CE. However, for this bias to occur the features and responses need to form a multidimensional representation which would be maintained active by the episodic buffer during the performance of the task. In the case of cueing tasks the representation would be formed by associations of the features of the symbolic cue and its respective direction on space. It seems that neither the episodic buffer nor the CE are responsible for the binding of features into perceived objects (Baddeley, 2012). A speculative idea is that these representations would depend on activations of sensory areas together with areas that decode spatial orienting responses such as the FEF and SMA. Previous studies showed that both areas are activated after presentation of symbolic cue in a cueing task (Corbetta & Shulman, 2002; Taylor *et al.*, 2008).

During the task the episodic buffer would hold temporarily the representations of the possible cues to be used by the CE as the attentional set. Signals that bias selection of the features and responses that compose representation are strengthened when behavior is successful which in turn reinforces the signals that compose representation. In other words, the representation with the greatest signal strength is temporarily maintained by the episodic buffer which activates the attentional set of the CE that modulate the signal strength of relevant ascending perceptual information forming a recurrent loop. This reinforcement of the attentional set, and hence the representation maintained by the episodic buffer, could eventually lead to a formation of a long term memory of the representation, which would be used directly to control behavior. For instance, it is suggested that arrows would have this representation on LTM allowing a fast response of directing attention when presented. Furthermore, strengthening of attentional set would also facilitate the processing of information and deliver of response along the task. This facilitation would involve faster performance and more resilience to interference which is related to an automatic processing, however, even facilitated this processing is still endogenous and depends on higher order functions. In contrast, when attentional set is being formed and contingencies of task are uncertain, i.e. low probabilistic relationship of stimuli, more resources from CE would be necessary so that orienting can occur and behavior unfolds. The necessity of more attentional and processing resources would be related to a voluntary control of attention which would be slower and prone to more errors. Therefore, it could be argued that when using a different number as cue in Chapter II would require more attentional resources to orient attention, and that is why behavioral and electrophysiological results show higher RTs and lower accuracy related to a lower modulation of the SPCN on posterior electrodes.

From this perspective, essentially what could be considered here as voluntary or automatized relates to the strength of the representation acquired along the task, and thus the amount of resources needed for processing the representation and deciding a proper response. Therefore, even with high attentional and processing demands orienting of attention seems to occur at short time intervals. The short temporal course for orienting attention even with high processing demands indicates how tasks with repetitive trials allow the acquisition of experiences that facilitate processing by employing memory-based strategies. These strategies would allow a rapid and perhaps effortless processing but still requiring same processing functions from WM. Supporting a similar perspective, Theeuwes (2018) suggests that visual selection is rarely voluntary in the sense of being slow, effortful and controlled, and rather visual selection is more often biased from selection history (based on past experience) which allows it to be fast and automatic. However, he argues that, in a cueing task, the fact that orienting of attention changes direction from trial to trial would be sufficient to render a truly voluntary example of top-down attention. Contrary to this idea are the results and interpretations reported here of what could be considered a truly voluntary and an automatized endogenous orienting of attention. From the aforementioned interpretations a truly voluntary orienting of attention may be just as rare as a voluntary visual selection.

The theoretical approach elaborated here of how automatized and voluntary endogenous orienting of attention could interrelate also has its roots on Logan’s instance theory of automatization (Logan, 1988) and Norman & Sallice theoretical framework of willed and automatic control of behavior (Norman & Shallice, 1986). For Norman & Shallice (1986) the several varieties of action performance that lay between a rapid and unaware action or controlled and conscious action could be comprehended from a theory of action which considered attention as a key component for controlling activation of response schemas. They considered that an action sequence were represented by a set of schemas that when triggered by an appropriate perceptual event would result in the sequential activation of structures responsible for conducting the action. If an action is well-learned than the activation of one schema could lead to activation of the set of schemas composing this action with little or no control of this activation leading to an automatic action. However, if an action is required by a novel or complex task then a supervisory attentional system (SAS), which was the theoretical basis for the central executive on WM model, would provide the control of schemas activation or inhibition. They propose that willed action would occur when it is required to resist a habitual action or when forced to perform an action. In these cases the SAS would produce attentional activation to modulate schema selection. Interestingly, they argue that the amount of activation and inhibition provided by SAS would correspond to a quantitative dimension of *will*, therefore control of action could be comprehended by an activation value that vary in a continuum. This would explain how distinctions between performance of action are clear when considering extremes such as well-learned and novel actions, but when considering a variety of other performances they fail to show a precise distinction of automatic or willed action. In a similar way for the framework considered here, the strength of the attentional set which is related to activations and inhibitions that would maintain the representation of cue-direction of attention in episodic memory could also be seen as a value in a continuum which is congruent with results showing poor performance with more demanding task conditions but not necessarily extinguishing attentional orienting effects.

Furthermore, Logan's (1988) theory poses that automaticity is memory retrieval, and that performance is automatized when it can rely directly on past memory solutions of a problem. The theory assumes that in the beginning of a task subjects use a general algorithm that is sufficient to perform the task, and as they acquire more experience specific solutions are learned from specific problems. When these specific problems appear again they retrieve the specific solutions from memory each time faster and easier until the general algorithm is abandoned completely. Therefore, each encounter with a problem (or stimulus) is encoded, stored and retrieved separately, that is why is considered an instance theory relating to theories of episodic memory. Attention in this theory has a relevant role since it considers that encoding to and retrieving from memory are consequences of attention, and therefore they are linked by attention. Basically, automaticity would involve a learning mechanism through accumulation of episodic traces with experience that allow a gradual transition from algorithmic processing to memory-based processing. This assumption is similar to the one considered for the framework reported here since a learning mechanism, although not necessarily from episodic traces but also from implicit learning, is necessary for the orienting process to become more automatic. Also, this theory seems to give an interesting point of view when considering attention as a relevant process in automatic performance, so that automaticity does not necessarily occur without attention contrary to what is suggested by other theories, and in agreement with the idea of an automatization of attentional control.

7. Conclusion and perspectives

The studies reported here investigated the involvement of voluntary and automatic control processes on endogenous orienting of attention. For this, temporal courses of what is considered to involve voluntary and automatic orienting of attention were explored behaviorally and electrophysiologically. The studies used variants of the classical cueing task in order to avoid the repetitive associations between presentation of symbolic cue and presentation of target at the cued location. Also, the speed of visual processing was explored when attention was shifted by different types of cues that would require distinct attentional control processes.

Results showed that inserting a relevant stimulus between cue and target presentation, thus avoiding cue-target associations, disrupted orienting of attention by extinguishing validity effect at 150 ms SOA. Also, other results showed that when cues are established in a trial-by-trial manner by a rule, in order to avoid repetitive cue-target associations, discrimination of target is decreased when attention is oriented by a cue that is conflicting with the rule. However, despite the interference, validity effect was observed at 250 ms SOA. Furthermore, the temporal courses for orienting of attention when using shape cues or choice cue are similar, and can occur at 200 ms SOA. Therefore, results demonstrate that endogenous orienting of attention can occur with a time interval as short as 200 ms even when implicit learning of cue-target associations are disrupted and more attentional resources are required.

Studies indicated that endogenous orienting of attention can occur in short time intervals even with high processing demands such as when direction of attention is guided by conflicting cues and choice cue. However, even though these high processing demands do not limit the temporal course of orienting of attention they do interfere with it causing a poor detection of target. Therefore, it seems that control of orienting of attention can be fast even when involving complex processing because of strategies based on repetitive experiences that would assist performance on cueing tasks.

The theoretical framework proposed here try to comprehend the results based on the idea that implicit and explicit learning mechanisms would form and reinforce representations of the association between cues and direction of attention. For that to occur it would require the function of working memory components such as the central executive and the episodic buffer which allow an interface with LTM. Therefore, voluntary and automatic control processes of endogenous orienting of attention are related with the strength of the representations of cue-direction of attention that determine the performance of the cueing task.

Further studies could be conducted in order to elucidate and explore the ideas presented here:

- Investigate whether endogenous orienting of attention at 100 ms or 150 ms SOA would be disrupted completely for tasks like the ones presented in Chapter II and Chapter III
- Track the effects of orienting attention by blocks of trials for different types of cues to observe if the amount of trials would influence differently when orienting processes are controlled by stronger or weaker representations
- Volitional control of attention could be better explored by using choice cue when controlling for the influence of previous trials
- Investigate the effects of high working memory load on orienting of attention after training for acquiring stronger representations
- Vocal rehearsal could be used to understand how the phonological loop could interfere with strengthening of representation in a cueing task
- Understand how imagery training compared to visual training would influence performance in a cueing task

8. References

Asaad, W. F., Rainer, G., & Miller, E. K. (1998). Neural activity in the primate prefrontal cortex during associative learning. Neuron. 21(6), 1399-1407. doi: 10.1016/S0896-6273(00)80658-3

Awh, E., Belopolsky, A.V. & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: a failed theoretical dichotomy. Trends in Cognitive Sciences. 16, 8. 437-443. doi: 10.1016/j.tics.2012.06.010

Baddeley, A. D., & Hitch, G. (1974). Working memory. In Psychology of learning and motivation. 8, 47-89. Academic press. doi: 10.1016/S0079-7421(08)60452-1

Baddeley, A. (2000). The episodic buffer: a new component of working memory? Trends in cognitive sciences. 4(11), 417-423. doi: 10.1016/S1364-6613(00)01538-2

Baddeley, A. (2012). Working Memory : Theories, Models, and Controversies. Annual review of psychology. 63,1-29. doi: 10.1146/annurev-psych-120710-100422

Bartholow, B. D., Pearson, M. A., Dickter, C. L., Sher, K. J., Fabiani, M. & Gratton, G. (2005) Strategic control and medial frontal negativity: Beyond errors and response conflict. Psychophysiology. 42(1), 33-42. doi: 10.1111/j.1469-8986.2005.00258.x

Bengson, J. J., Kelley, T. A., Zhang, X., Wang, J., & Mangun, G. R. (2014). Spontaneous Neural Fluctuations Predict Decisions to Attend. J Cogn Neurosci. 26(11),2578–2584. doi: 10.1162/jocn

Bengson, J. J., Kelley, T. A. & Mangun, G. R. (2015). The neural correlates of volitional attention: A combined fMRI and ERP study. Human Brain Mapping. 36(7), 2443-2454. doi: 10.1002/hbm.22783

Bichot, N. P., Schall, J. D., & Thompson, K. G. (1996). Visual feature selectivity in frontal eye fields induced by experience in mature macaques. Nature. 381(6584), 697–699.

Botvinick, M. M., Cohen, J.D., & Carter, C.S. (2004). Conflict monitoring and anterior cingulate cortex: an update.Trends Cogn Sci. 8(12):539-46. doi: 10.1016/j.tics.2004.10.003

Brignani, D., Guzzon, D., Marzi, C. A., & Miniussi, C. (2009) Attentional orienting induced by arrows and eye-gaze compared with an endogenous cue. Neuropsychologia. 47(2):370-381. doi: 10.1016/j.neuropsychologia.2008.09.011.

Broadbent, D.E. (1958). Effect of Noise on an “Intellectual” Task. The Journal of the Acoustical Society of America. 30, 824-827. doi:10.1121/1.1909779

Broadbent, D. E. (1982). Task combination and selective intake of information. Acta Psychologica. 50(3), 253-290. doi: 10.1016/0001-6918(82)90043-9

Carter, C.S. & van Veen, V. (2007) Anterior cingulate cortex and conflict detection: An update of theory and data. Cognitive, Affective, & Behavioral Neuroscience. 7(4), 367-379. doi: 10.3758/CABN.7.4.367

Castro-Barros, B. A., Righi, L. L., Grechi, G. & Ribeiro-do-Valle, L. E. (2008). Interlateral asymmetry in the time course of the effect of a peripheral prime stimulusBrain and Cognition. 66(3), 265-279. doi: 10.1016/j.bandc.2007.09.007

Chica, A. B., Martín-Arévalo, E., Botta, F., & Lupiáñez, J. (2014). The Spatial Orienting paradigm: How to design and interpret spatial attention experiments. Neuroscience and Biobehavioral Reviews. 40, 35–51. doi: 10.1016/j.neubiorev.2014.01.002

Cheal, M.L. & Lyon, D.R. (1991). Central and peripheral precuing of forced-choice discrimination. The Quarterly Journal of Experimental Psychology. 43(4),859–880. doi: 10.1080/14640749108400960

Corbetta, M., Kincade, J. M., Ollinger, J. M., McAvoy, M. P. & Shulman, G. L. (2000). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. Nature Neuroscience. 3(3), 292-297.

Corbetta, M. & Shulman, G.L. (2002). Control of goal-directed and stimulus driven attention in the brain. Nat. Rev., Neurosci. 3, 201–215.doi: 10.1038/nrn755

Courtney, S. M., Petit, L., Maisog, M., Ungerleider, L. G., & Haxby, J. V. (1998). An area specialized for spatial working memory in human frontal cortex. Science. 279(5355),1347-1351. doi: 10.1126/science.279.5355.1347.

Desimone, R. & Duncan, J. (1995). Neural Mechanisms of Selective Visual Attention. Annual Review of Neuroscience.18(1), 193-222. doi: 10.1146/annurev.ne.18.030195.001205.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. Psychological Review. 70(1), 80-90. doi: 10.1037/h0039515

Dodd, M. D., & Wilson, D. (2009). Training attention : Interactions between central cues and reflexive attention. Visual Cognition. 17(5),736-754. doi: 10.1080/13506280802340711

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E. & Baron-Cohen, S. (1999) Gaze Perception Triggers Reflexive Visuospatial Orienting. Visual Cognition. 6(5),509-540. doi: 10.1080/135062899394920

Duncan, J. & Owen, A. M. (2000) Common regions of the human frontal lobe recruited by diverse cognitive demands. Trends in Neuroscience. 23(10), 475-483. doi: 10.1016/S0166-2236(00)01633-7

Eimer, M. (1994). An ERP study on visual spatial priming with peripheral onsets. Psychophysiology. 31(2),154-163. doi: 10.1111/j.1469-8986.1994.tb01035.x

Eimer, M. (1996). The N2pc component as an indicator of attentional selectivity. Electroencephalogr Clin Neurophysiol. 99, 3. 225-34. doi: 0.1016/0013-4694(96)95711-9

Eimer, M. (2014). The neural basis of attentional control in visual search. Trends in Cognitive Sciences, 18(10), 526-535. doi: 10.1016/j.tics.2014.05.005

Eriksen, C.W. & Hoffman, J.E. (1972). Temporal and spatial characteristics of selective encoding from visual displays. Perception & Psychophysics. 12(2), 201-204. doi:10.3758/BF03212870

Fischer, M. H., Castel, A. D., Dodd, M. D., & Pratt, J. (2003). Perceiving numbers causes spatial shifts of attention. 6(6), 555–556. doi: 10.1038/nn1066

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary Covert Orienting Is Contingent on Attentional Control Settings. Journal of Experimental Psychology: Human Perception and Performance. 18(4), 1030-1044. doi: 10.1037/0096-1523.18.4.1030

Folstein, J. R. & Petten, C. V. (2007) Influence of cognitive control and mismatch on the N2 component of the ERP: A review. Psychophysiology. 45(1),152-170. doi: 10.1111/j.1469-8986.2007.00602.x

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by non predictive gaze. Psychonomic Bulletin & Review, 5(3), 490−495. doi: 10.3758/BF03208827

Funahashi, S. (2006) Prefrontal cortex and working memory processes. Neuroscience. 139, 251–261. doi:10.1016/j.neuroscience.2005.07.003

Green, J. J. & McDonald, J. J. (2008) Electrical neuroimaging reveals timing of attentional control activity in human brain. PLOS Bio 6(4),e81,730-738. doi:10.1371/journal.pbio.0060081.

Guzzon, D., Brignani, D., Miniussi, C., & Marzi, C. A. (2010). Orienting of attention with eye and arrow cues and the effect of overtraining. Acta Psychologica, 134(3), 353–362. doi: 10.1016/j.actpsy.2010.03.008

Harter, M., Miller, S. L., Price, N. J., LaLonde, M. E. & Keyes, A. L. (1989) Neural Processes Involved in Directing Attention. Journal of Cognitive Neuroscience. 1 (3), 223-237. doi: 10.1162/jocn.1989.1.3.223

Harter, M. & Anllo-Vento, L. (1991) Visual-spatial attention: preparation and selection in children and adults. In: Brunia CHM, Verbaten MN, editors. Event-related brain research, Amsterdam: Elsevier, 183-194.

Hillyard, S. A., Vogel, E. K. & Luck, S. J. (1998) Sensory gain control (amplification) as a mechanism of selective attention: electrophysiological and neuroimaging evidence. *Phil. Trans. R. Soc. Lond. B*. 353(1373), 1257-1270. doi: 10.1098/rstb.1998.0281

Hopf, J.M. & Mangun, G.R. (2000). Shifting visual attention in space: an electrophysiological analysis using high spatial resolution mapping. Clin. Neurophysiol. 111, 1241–1257. doi: 10.1016/S1388-2457(00)00313-8

Hopfinger, J. B., Camblin, C. C., & Parks, E. L. (2010). Isolating the internal in endogenous attention. Psychophysiology. 47(4), 739–747. doi: 10.1111/j.1469-8986.2010.00981.x

Hopfinger, J. B. & Mangun, G. R. (1998). Reflexive Attention Modulates Processing of Visual Stimuli in Human Extrastriate Cortex. Psychological Science. 9(6), 441-447. doi: 10.1111/1467-9280.00083

JASP Team (2019). JASP (Version 0.10.2)[Computer software]

Jenkins, M., Grubert, A., & Eimer, M. (2018). The speed of voluntary and priority-driven shifts of visual attention. Journal of Experimental Psychology: Human Perception and Performance. 44(1), 27-37. doi: 10.1037/xhp0000438

Jolicoeur P, Sessa P, Dell'Acqua R, & Robitaille N. (2006) On the control of visual spatial attention: evidence from human electrophysiology. Psychological Research. 70:414–424.doi: 10.1007/s00426-005-0008-4

Jongen, E. M., & Smulders, F. T. (2007). Sequence effects in a spatial cueing task: Endogenous orienting is sensitive to orienting in the preceding trial. Psychological Research. 71(5), 516-523. doi: 10.1007/s00426-006-0065-3

Jonides J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J.B. Long & A.D. Baddeley (Eds.), Attention and performance. IX. Hillsdale, NJ:Lawrence Erlbaum Associates.pp. 187–203.

Kastner, S. & Ungerleider, L.G. (2000). Mechanisms of visual attention in the human cortex. Ann. Rev. Neurosci. 23, 315–341. doi: 10.1146/annurev.neuro.23.1.315

Keller, J. M. (2008). An integrative theory of motivation, volition, and performance. Technology, Instruction, Cognition, and Learning. 6(2), 79-104.

Kimble, G. A., & Perlmuter, L. C. (1970). The problem of volition. Psychological Review, 77(5), 361-384. doi: 10.1037/h0029782

Kiss, M., Van Velzen, J., & Eimer, M. (2008). The N2pc component and its links to attention shifts and spatially selective visual processing. Psychophysiology, *45*(2), 240–249. doi: 10.1111/j.1469-8986.2007.00611.x

Klein, M. R. (1988) Inhibitory tagging system facilitates visual search. Nature. 334(6181):430-431. doi:10.1038/334430a0

Klein, R. (2009). On the control of attention. Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale, 63(3), 240–252. doi: 10.1037/a0015807

Larson, M. J., Clayson, P. E., & Clawson, A. (2014) Making sense of all the conflict: A theoretical review and critique of conflict-related ERPs. International Journal of Psychophysiology 93(3), 283–297. doi: 10.1016/j.ijpsycho.2014.06.007

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*(4), 492-527. doi:10.1037/0033-295X.95.4.492

Luck, S. J., & Hillyard, S. A. (1990). Electrophysiological evidence for parallel and serial processing during visual search. 48(6), 603–617.doi: 10.3758/BF03211606

Luck, S. J., & Hillyard, S. A. (1994a). Spatial filtering during visual search: Evidence from human electrophysiology. Journal of Experimental Psychology: Human Perception and Performance. 20(5), 1000-1014. doi: 10.1037/0096-1523.20.5.1000

Luck, S. J., & Hillyard, S. A. (1994b). Electrophysiological correlates of feature analysis during visual search. Psychophysiology, 31(3), 291-308. doi: 10.1111/j.1469-8986.1994.tb02218.x

Luck, S. J., & Vecera, S. P. (2002). Attention. In S. Yantis (Ed.), Stevens' Handbook of Experimental Psychology: Vol. 1: Sensation and Perception (3rd ed., pp. 235-286). New York: Wiley.

Luck, S. J. (2014). An Introduction to the Event-Related Potential Technique, Second Edition. Cambridge, MA: MIT Press.

Mangun G.R., & Hillyard S.A. (1987). The Spatial Allocation of Visual Attention as Indexed by Event-Related Brain Potentials. Human Factors. 29(2),195-211.

Mangun, G. R. (1985). Neural mechanisms of visual selective attention. Psychophysiology. 32(1),4-18. doi: 10.1111/j.1469-8986.1995.tb03400.x

Mangun, G. R., & Hillyard, S. A. (1991). Modulations of Sensory-Evoked Brain Potentials Indicate Changes in Perceptual Processing During Visual-Spatial Priming. Journal of Experimental Psychology: Human Perception and Performance, 17(4), 1057–1074. doi: 10.1037/0096-1523.17.4.1057

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. Annual review of neuroscience. 24(1),167-202. doi: 10.1146/annurev.neuro.24.1.167

Muller, H.J. & Rabbitt, P.M. (1989). Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption. J Exp Psychol Hum Percept Perform. 15(2), 315−330.doi: 10.1037/0096-1523.15.2.315

Nobre, A. C., Sebestyen, G. N., & Miniussi, C. (2000). The dynamics of shifting visuospatial attention revealed by event-related potentials. *Neuropsychologia*, *38*(7), 964–974. doi: 10.1016/S0028-3932(00)00015-4

Norman, D. A., & Shallice, T. (1986). Attention to action. In Consciousness and self-regulation (pp. 1-18). Springer, Boston, MA.

Olivers, C. N., & Eimer, M. (2011). On the difference between working memory and attentional set. Neuropsychologia. *49*(6), 1553-1558. doi: 10.1016/j.neuropsychologia.2010.11.033

Olk, B., Tsankova, E, Petca, A. R. & Wilhelm, A. F. X. (2014) Measuring effects of voluntary attention: A comparison among predictive arrow, colour, and number cues. Q J of Exp Psychol, 67(10), 2025-2041, doi:10.1080/17470218.2014.898670

Posner, M. I. (1980). Orienting of Attention. Q J of Exp Psychol. 32(1), 3-25. doi: 10.1080/00335558008248231

Posner, M. I., Cohen, Y., & Rafal, R. D. (1982). Neural Systems Control of Spatial Orienting. Philosophical Transactions of the Royal Society B: Biological Sciences, 298, 187-198. doi: 10.1098/rstb.1982.0081

Posner, M.I. & Cohen, Y. (1984). Components of visual orienting. In Bouma, H.; Bouwhuis, D., Attention and Performance X: Control of language processes. Hillsdale, NJ: Erlbaum. pp. 531–556.

Posner, M.I., Rafal, R.D., Choate, L., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. Cognitive Neuropsychology. 2, 211-228. doi:10.1080/02643298508252866

Posner, M. I. (2016) Orienting of attention: then and now. Q J Exp Psychol. 69(10): 1864–1875. doi:10.1080/17470218.2014.937446

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. Behavior Research Methods. doi:10.3758/s13428-018-01193-y

Petersen, S. E. & Posner, M. I. (2012). The Attention System of the Human Brain: 20 Years After. Annu Rev Neurosci. 35, 73–89. doi: 10.1146/annurev-neuro-062111-150525

Praamstra, P., Boutsen, L. & Humphreys, G. W. (2005) Frontoparietal Control of Spatial Attention and Motor Intention in Human EEG. 94(1), 764-774. doi: 10.1152/jn.01052.2004

Qian, Q., Shinomori, K., & Song, M. (2012). Sequence effects by non-predictive arrow cues. Psychological research. 76(3), 253-262. doi: 10.1007/s00426-011-0339-2

Ristic, J., Friesen, C. K. & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. Psychon Bull. 9(3), 507–513. doi: 10.3758/BF03196306

Ristic, J. & Kingstone, A. (2012). A new form of human spatial attention: Automated symbolic orienting. Visual Cognition. 20(3), 244-264. doi: 10.1080/13506285.2012.658101

Ristic, J., Landry, M., & Kingstone, A. (2012). Automated symbolic orienting: The missing link. *Frontiers in Psychology*, *3*(DEC), 1–7. doi: 10.3389/fpsyg.2012.00560

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review, 84(1), 1-66. doi: 10.1037/0033-295X.84.1.1

Sherrington, C. S. (1906).Yale University Mrs. Hepsa Ely Silliman memorial lectures. The integrative action of the nervous system. New Haven, CT, US: Yale University Press.

doi: 10.1037/13798-000

Smith, E. E. & Jonides, J. (1999) Storage and Executive Processes in the Frontal Lobes. Science. 283(5408), 1657-1661. doi: 10.1126/science.283.5408.1657

Sternberg, S., Knoll, R. L., & Gates, B. A. (1971, November). Prior entry reexamined: Effect of attentional bias on order perception. In Meeting of the Psychonomic Society, St. Louis, MO.

Stelmach, L. B., & Herdman, C. M. (1991). Directed attention and perception of temporal order. Journal of Experimental Psychology: Human Perception and Performance, 17(2), 539-550. doi: 10.1037/0096-1523.17.2.539

Sumner, P., Nachev, P., Morris, P., Peters, A. M., Jackson, S. R., Kennard, C. & Husain, M. (2007) Human Medial Frontal Cortex Mediates Unconscious Inhibition of Voluntary Action. Neuron. 54(5), 697-711. doi: 10.1016/j.neuron.2007.05.016

Tassinari, G., Aglioti, S., Chelazzi, L., Peru, A. & Berlucchi, G. (1994) Do peripheral non-informative cues induce early facilitation of target detection? Vis Res. 34(2),179–189. doi: 10.1016/0042-6989(94)90330-1

Tamber-Rosenau, B.J. & Marois, R. (2016). Central attention is serial, but midlevel and peripheral attention are parallel—A hypothesis Atten Percept Psychophys (2016) 78(7), 1874-1888. doi: 10.3758/s13414-016-1171-y

Tait D.S., & Brown V.J. (2010) Attentional Set. In: Stolerman I.P. (eds) Encyclopedia of Psychopharmacology. Springer, Berlin, Heidelberg doi: 10.1007/978-3-540-68706-1_1088

Taylor, P. C. J., Rushworth, M. F. S. & Nobre, A. C. (2008). Choosing Where to Attend and the Medial Frontal Cortex: An fMRI Study. J Neurophysiol. 100(3),1397-1406. doi: 10.1152/jn.90241.

Theeuwes, J. (1992). Perceptual selectivity for color and form. Perception & Psychophysics. 51(6), 599-606. doi: 10.3758/BF03211656

Theeuwes, J. (1993). Visual selective attention: A theoretical analysis. Acta Psychologica. 83(2), 93-154. doi: 10.1016/0001-6918(93)90042-P

Theeuwes, J. (2018). Visual Selection: Usually Fast and Automatic; Seldom Slow and Volitional. Journal of Cognition. 1(1), 29. doi: 10.5334/joc.13

Tipples, J., 2002. Eye gaze is not unique: automatic orienting in response to uninformative arrows. Psychon. Bull. 9(2), 314–318.doi: 10.3758/BF03196287

Treisman, A.M. (1960) Contextual cues in selective listening. Quarterly Journal of Experimental Psychology. 12(4), 242-248. doi:10.1080/17470216008416732 Treisman, A. M. (1964) Selective attention in man. British Medical Bulletin. 20(1),12–16. doi: 10.1093/oxfordjournals.bmb.a070274

Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review*, *76*(3), 282–299. doi: 10.1037/h0027242

Treisman, A.M. & Gelade, G. (1980). A feature-integration theory of attention. Cognitive Psychology.12(1), 97-136. doi: 10.1016/0010-0285(80)90005-5

van Velzen, J. & Eimer, M. (2003) Early posterior ERP components do not reflect the control of attentional shifts toward expected peripheral events. Psychophysiology. 40(5):827-831. doi:10.1111/1469-8986.00083

Van Voorhis, S. & Hillyard, S.A. (1977) Visual evoked potentials and selective attention to points in space. Perception & Psychophysics (1977) 22(1), 54-62. doi: 10.3758/BF03206080

Vogel EK, Machizawa MG. Neural activity predicts individual differences in visual working memory capacity. Nature. 2004; 428:748–751.

Vossen, A. Y., Ross, V., Jongen, E. M., Ruiter, R. A., & Smulders, F. T. (2016). Effect of working memory load on electrophysiological markers of visuospatial orienting in a spatial cueing task simulating a traffic situation. Psychophysiology. 53(2), 237-251. doi: 10.1111/psyp.12572

Woodman, G. F., & Luck, S. J. (2007). Do the contents of visual working memory automatically influence attentional selection during visual search? Journal of Experimental Psychology: Human Perception and Performance, 33, 363-377. doi: 10.1037/0096-1523.33.2.363
Woodman, G.F., Aritaa J.T., Luck S.J. (2009) A cuing study of the N2pc component: An index of attentional deployment to objects rather than spatial locations. Brain Research 101-111. doi: 10.1016/j.brainres.2009.08.011.

Worden, M. S., Foxe, J. J., Wang, N., & Simpson, G. V. (2000). Anticipatory biasing of visuospatial attention indexed by retinotopically specific-band electroencephalography increases over occipital cortex. *J Neurosci. 20*(6), 1-6.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. Journal of Experimental Psychology: Human Perception and Performance. 16(1), 121-134. doi: 10.1037/0096-1523.16.1.121

9. Appendices

All the scripts for the tasks used here will be available at: https://github.com/elisajordao/taskCode

List of the following documents:

1) Human research ethics committee approval (IB – USP)

2) Human research ethics committee approval (UFABC)

3) Adapted Edinburgh handedness questionnaire

4) Health assessment questionaire

INSTITUTO DE BIOCIÊNCIAS DA UNIVERSIDADE DE SÃO PAULO - IBUSP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Orientação endógena da atenção em humanos envolve processos automáticos e processos voluntários?

Pesquisador: Elisa Mari Akagi Jordão

Área Temática:

Versão: 1

CAAE: 44577015.8.0000.5464

Instituição Proponente: Instituto de Biociências da Universidade de São Paulo - IBUSP

Patrocinador Principal: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

DADOS DO PARECER

Número do Parecer: 1.073.275

Data da Relatoria: 05/05/2015

Apresentação do Projeto:

Orientação endógena da atenção em humanos envolve processos automáticos e processos voluntários?

Objetivo da Pesquisa:

O projeto em questão trata do estudo de funções atencionais em humanos e envolve a proposta de coleta de dados tanto comportamentais quanto eletrofisiológicos.

Avaliação dos Riscos e Benefícios:

A tarefa comportamental, bem como as análises eletrofisiológicas propostas constam de métodos consagrados e que não trazem riscos aos voluntários se aplicadas de maneira padrão.

Comentários e Considerações sobre a Pesquisa:

Análise do projeto: a) amostra a ser analisada - Voluntários saudáveis sem distinção de preferências por gênero, entre 18 e 35 anos, com nível de instrução superior completo ou incompleto; b) procedimentos a que as pessoas serão submetidas - Avaliação do desempenho comportamento em tarefa atencional com auxílio de aparto computacional. Adicionalmente, alguns voluntários serão avaliados por meio de análise da atividade encefalográfica; c) infraestrutura disponível - Sala de experimentação, suporte computacional e equipamentos e eletroencefalografia; d) armazenamento de amostra - Os dados serão armazenados em mídia

Endereço: Rua do Matão, Travessa 14, nº 321
Bairro: Butantã **CEP:** 05.508-090
UF: SP **Município:** SAO PAULO
Telefone: (11)3091-7624 **Fax:** (11)3091-7624 **E-mail:** cepibusp@ib.usp.br

digital e está descrita a manutenção do sigilo para a necessária proteção da identidade dos voluntários; e) apoio financeiro - CAPES.

Considerações sobre os Termos de apresentação obrigatória:

O formulário com os Termos de Consentimento Livre e Esclarecido constam no projeto e estão de maneira apropriada.

Recomendações:

Os voluntários não poderão ser alunos do orientador do projeto para que não se configure conflito de interesse.

Deverá ser enviado a este Comitê, o documento de aprovação do Comitê do Centro de Matemática, Computação e Cognição, da Universidade Federal do ABC, que atua como coparticipante da pesquisa.

Conclusões ou Pendências e Lista de Inadequações:

Não há.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

SAO PAULO, 21 de Maio de 2015

Assinado por:
CELIA PRISZKULNIK KOIFFMANN
(Coordenador)

UFABC

UNIVERSIDADE FEDERAL DO ABC

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

Elaborado pela Instituição Coparticipante

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Orientação endógena da atenção em humanos envolve processos automáticos e processos voluntários?

Pesquisador: Elisa Mari Akagi Jordão

Área Temática:

Versão: 1

CAAE: 44577015.8.3001.5594

Instituição Proponente: Instituto de Biociências da Universidade de São Paulo - IBUSP

Patrocinador Principal: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

DADOS DO PARECER

Número do Parecer: 1.101.624

Data da Relatoria: 10/06/2015

Apresentação do Projeto:

Trata-se de um estudo com experimento comportamental com registro eletrofisiológico (EEG) concomitante, em alguns grupos. Voluntários sadios participarão de um experimento em qual deverão detectar um sinal em um painel de LEDs, após uma pista simbólica, antes ou depois de uma pista temporal. Os voluntários são submetidos a uma adaptação do paradigma de Posner, com manipulação da validade de pistas simbólicas centrais preditivas ou não-preditivas e com variação das assincronias entre os estímulos visando criar condições diferentes de alocação de atenção voluntária e automática endógena.

Objetivo da Pesquisa:

Os pesquisadores esperam obter evidências da existência de uma modalidade atencional ao mesmo tempo endógena e automática, além das tradicionais endógena/voluntária e exógena/automática. Este modo de atenção seria o resultado de um processo semelhante ao condicionamento clássico e caracterizado pela velocidade do surgimento do efeito atencional. Ao aplicar, simultaneamente, a eletroencefalografia, os autores do estudo esperam encontrar assinaturas eletrofisiológicas no sinal-PRE para a dinâmica atencional.

Avaliação dos Riscos e Benefícios:

O estudo não traz benefícios imediatos aos voluntários - é um estudo acadêmico que visa a ampliação do conhecimento sobre a alocação da atenção.

Sobre os riscos, os pesquisadores afirmam que "O tipo de experimento, seja comportamental ou eletrofisiológico, não traz nenhum risco, seja físico, psíquico ou de saúde, ao voluntário." É provavelmente verdade que os procedimentos estipulados no estudo não literalmente trazem risco à vida ou ao saúde dos voluntários, a resolução que trata da pesquisa em seres humanos, CNS 466/12, classifica riscos e desconfortos na mesma categoria - v. II.2.2, a definição do Termo de Consentimento, "... potenciais riscos e o incômodo que esta [= a pesquisa] possa lhes acarretar", em III.1, sobre eticidade, "d) buscar sempre que prevaleçam os benefícios esperados sobre os riscos e/ou desconfortos previsíveis;" e IV.3, sobre o Termo de Consentimento, "b) explicitação dos possíveis desconfortos e riscos decorrentes da participação na pesquisa, ...". Ainda estipula, em V, que "Toda pesquisa com seres humanos envolve risco em tipos e gradações variados." o que seria incompatível com uma afirmação de que não há riscos neste estudo em particular. Em outros estudos analisados envolvendo EEG e métodos psicofísicos, este CEP tem considerado que o uso do gel condutivo (mesmo hipoalergênico) e da touca de eletrodos durante a administração do EEG é um desconforto deva ser mencionado, como também a possível ocorrência de cansaço ou sonolência durante o experimento comportamental, ainda mais aplicado em uma sala escura.

Comentários e Considerações sobre a Pesquisa:

A pesquisa é relevante e os métodos adequados para os objetivos. Os benefícios são maiores que os incômodos para os participantes.

Considerações sobre os Termos de apresentação obrigatória:

O TCLE é breve e claro, embora que não dá nenhum detalhe sobre o procedimento que será adotado durante o experimento. O TCLE, diferente das informações inseridas no Plataforma Brasil, menciona os possíveis desconfortos, mas somente relacionado ao procedimento comportamental: "No entanto, é possível sentir certo desconforto ou cansaço devido à duração da tarefa."

Folha de Rosto (sem CNPJ) e Termo de Anuência são assinados.

Recomendações:

Retirada do local no TCLE ("São Paulo") próximo à assinatura caso parte da coleta de dados se der em São Bernardo do Campo.

Conclusões ou Pendências e Lista de Inadequações:

Pelo fato do TCLE ser um pouco mais explícito sobre a possibilidade de desconforto que o campo de riscos submetido no Plataforma Brasil, e considerando que a alternativa é uma submissão nova do projeto, o protocolo como um todo é marginalmente aceitável. O CEP-UFABC pede que a

Questionário de Edinburgh (adaptado)

Nome ____________________________________ Idade ___ anos
Se você é destro, já teve alguma tendência a ser canhoto? _____
Existe algum canhoto na sua família?______________________
Indicar a preferência manual nas atividades abaixo. Assinale:
"XX" na coluna apropriada quando a preferência for tão forte que você **nunca use a outra mão.**
"XX" e "X" nas colunas apropriadas quando **preferir usar uma das mãos, mas de vez em quando também usar a outra.**
"XX" nas duas colunas quando **usar indistintamente qualquer uma das mãos.**

Atividades	Direita	Esquerda
Escrever		
Desenhar		
Jogar uma pedra		
Usar uma tesoura		
Usar um pente		
Usar uma escova de dentes		
Usar uma faca (sem o uso do garfo)		
Usar uma colher		
Usar um martelo		
Usar uma chave de fendas		
Usar uma raquete de ping-pong		
Usar uma faca (com o garfo)		
Usar uma vassoura (mão superior)		
Usar um rodo (mão superior)		
Acender um fósforo		
Abrir um vidro com tampa (mão que segura a tampa)		
Distribuir cartas		
Enfiar a linha na agulha (mão que segura a linha)		
Total (deixar em branco)		

Dominância pedal (chutar uma bola) ___________________________________
Dominância Visual Apontando ________ Fotografando _______
Acuidade Visual OE _______ OD _______ OE+OD _______
Duração média do sono _______ **Horário Preferido para Acordar** _______
Medicamentos em Uso ____
Hábito de Brincar com jogos eletrônicos:
Sim ( ) Não ( )
Mulheres:
Data da última menstruação ________ **Regularidade do ciclo** _______
Quociente de Lateralidade [(D-E)/(D+E)] ________
(deixar em branco)

Avaliação do estado de saúde

O(A) Sr(a). poderia, por favor, responder às seguintes perguntas a respeito de sua saúde:

1. Tem dores de cabeça freqüentes?..SIM □ NÃO □

2. Tem falta de apetite?..SIM □ NÃO □

3. Dorme mal?...SIM □ NÃO □

4. Assusta-se com facilidade?...SIM □ NÃO □

5. Tem tremores na mão?...SIM □ NÃO □

6. Sente-se nervoso(a), tenso(a) ou preocupado(a)?...SIM □ NÃO □

7. Tem má digestão?...SIM □ NÃO □

8. Tem dificuldade de pensar com clareza?..SIM □ NÃO □

9. Tem se sentido triste ultimamente?...SIM □ NÃO □

10. Tem chorado mais do que de costume?...SIM □ NÃO □

11. Encontra dificuldades para realizar com satisfação as suas atividades diárias?…... SIM □ NÃO □

12. Tem dificuldades para tomar decisões?...SIM □ NÃO □

13. Tem dificuldades no serviço (seu trabalho é penoso, lhe causa sofrimento)?…….. SIM □ NÃO □

14. É incapaz de desempenhar um papel útil em sua vida?...................................SIM □ NÃO □

15. Tem perdido o interesse pelas coisas?..SIM □ NÃO □

16. Você se sente uma pessoa inútil, sem préstimo?..SIM □ NÃO □

17. Tem tido a idéia de acabar coma vida?...SIM □ NÃO □

18. Sente-se cansado(a) o tempo todo?...SIM □ NÃO □

19. Tem sensações desagradáveis no estômago?..SIM □ NÃO □

20. Você se cansa com facilidade?... SIM □ NÃO □