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Implicit learning: A way to improve visual search in spatial neglect?

Murielle Wansard [a,*], Marie Geurten [a], Catherine Colson [b], Thierry Meulemans [a]

[a] Department of Psychology, Cognition and Behavior, Neuropsychology Unit, University of Liège, Belgium
[b] Service de Revalidation Neurologique, CHU Brugmann, Bruxelles, Belgium

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ABSTRACT

Studies have shown that neglect patients are able to use stimulus regularities to orient faster toward the neglected side, without necessarily being aware of that information, or at the very least without being able to verbalize their knowledge. In order to better control for the involvement of explicit processes, the present study sought to test neglect patients' ability to detect more complex associations between stimuli using tasks similar to those used in implicit learning studies. Our results demonstrate that neglect patients had difficulties implicitly learning complex associations, contrary to what we found with controls. The possible influence of attentional and working memory impairments are discussed.

1. Introduction

Right hemisphere damage following stroke is well known to lead to spatial neglect, particularly when distributed fronto-parietal networks are involved (Bartolomeo, Thiebaut de Schotten, & Doricchi, 2007; Bartolomeo, Zieren, Vohn, Dubois, & Sturm, 2008; Corbetta & Shulman, 2002; Ptak & Schnider, 2011). Neglect is characterized by an inability to detect events or to initiate motor responses towards the contralateral side of the brain lesion (Heilman, Watson, & Valenstein, 1984). Patients suffering from spatial neglect are frequently unaware of their difficulty (anosognosia). Consequently, they do not develop compensatory strategies in their daily life to orient their attention toward the left (Bartolomeo, 2014; Vuilleumier & Vocat, 2011). Although different impairments may contribute to the syndrome (including non-spatial deficits such as low levels of vigilance or arousal; see e.g., Malhotra, Coulthard, & Husain, 2009; Robertson, 2001), deficits in spatial attention are the core symptoms of neglect, including an inability to orient attention toward the contralesional left hemispace (Bartolomeo & Chokron, 2002) and difficulty disengaging attention from items on the right side (for a review, see Bartolomeo, Thiebaut de Schotten, & Chica, 2012).

To deal with the massive amount of information available in our environment, our visual system must rapidly prioritize and select stimuli based on their pertinence either in terms of salience (e.g., potentially dangerous events) or their relevance to the observer's internal goals and expectancies (Chica, Bartolomeo, & Lupianez, 2013; Ruz & Lupiáñez, 2002). This process of selection thus involves two modes of attentional orienting: attention can be directed to an object in space either automatically, in a relatively reflexive way (exogenous orienting), or in a more voluntary and controlled mode (endogenous

* Corresponding author at: Department of Psychology, Cognition & Behavior, Boulevard du Rectorat, B33, B-4000 Liège, Belgium.
E-mail address: m.wansard@ulg.ac.be (M. Wansard).

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orienting; Bartolomeo et al., 2012; Chica, Lupianez, & Bartolomeo, 2006; Fecteau & Munoz, 2006; Itti, Koch, Way, & Angeles, 2001).

Attentional orienting has been extensively studied in spatial neglect using the simple manual reaction tasks developed by Posner (1980). These studies showed that exogenous orienting is particularly impaired in spatial neglect, with an initial orienting of attention towards the right side, followed by a difficulty in disengaging attention in order to reorient it leftward (Bartolomeo & Chokron, 2002; Bartolomeo, Decaix, Siéroff, & Chokron, 2001; Chica et al., 2011, 2013; Gainotti, D'Erme, & Bartolomeo, 1991; Losier & Klein, 2001; Natale, Posteraro, Prior, & Marzi, 2005; Posner, Walker, Friedrich, & Rafal, 1984; Smania et al., 1998). Interestingly, endogenous orienting seems to be relatively spared, albeit slowed, in neglect patients. The use of central spatial cues (e.g., an arrow indicating target location) or peripheral cues that are spatially predictive of the future location of the target (e.g., following a cue, the target will appear with high probability in the uncued location) can help neglect patients to orient leftward (Bartolomeo et al., 2001; Ladavas, Carletti, & Gori, 1994; Natale et al., 2005; Smania et al., 1998). However, although intact endogenous processes improve response times and accuracy in the detection of stimuli on the left side, they are not sufficient to completely abolish signs of neglect (Chica & Bartolomeo, 2012; Natale et al., 2005; Siéroff, Decaix, Chokron, & Bartolomeo, 2007).

Moreover, in Bartolomeo et al. (2001), although participants were informed of the cue's predictability before the experiment, some claimed not to have used this information to respond more quickly or precisely to targets. Thus, motivated strategic considerations or voluntary control (referred as endogenous orienting) may not be required to observe these attentional effects. In this sense, Lambert, Naikar, McLachlan, and Aitken (1999) questioned the purely controlled nature of endogenous orienting by demonstrating that visual orienting can occur independently of explicit knowledge of the predictive value of the cue (Chica & Bartolomeo, 2010; Chun, 2000; Lambert, 2003; Lopez-Ramon, Chica, Bartolomeo, & Lupiáñez, 2011; Risko & Stolz, 2010; Turk-Browne, Jungé, & Scholl, 2005; Zhao, Al-Aidroos, & Turk-Browne, 2013). Similarly, Bartolomeo, Decaix, and Siéroff (2007) found that subjects' sensitivity to the probabilistic association between cues and targets in the Posner paradigm might be sustained by more implicit mechanisms, operating independent of consciousness or verbal reports (see also Decaix, Siéroff, & Bartolomeo, 2002; Rieth & Hubert, 2013).

Recently, we demonstrated that some neglect patients were able to exploit the predictive value of cues presented on the right side to respond more quickly and accurately toward the neglected space without necessarily being able to describe the cue-target relationship (Wansard, Bartolomeo, Vanderaspoilden, Geurten, & Meulemans, 2015). In a Posner spatial cueing task, we distributed presentation of a peripheral cue such that the target appeared with high probability on the opposite side of space (80% invalid trials). The most effective strategy was therefore to orient attention towards the side opposite to the cue. Interestingly, in this study, neglect patients were able to inhibit the capture of attention from right ipsilateral cues and reorient toward contralesional targets without necessarily being aware of the cue-target relationship. This finding suggests that the probabilistic association between cues and targets location might be sustained by implicit processes, which might be preserved in some neglect patients.

Other studies have investigated implicit processes (and more specifically spatial priming and statistical learning) in right brain-damaged patients with or without spatial neglect (for a recent review, see Shaqiri, Anderson, & Danckert, 2013). Using a visual search task in which a target's location was repeated across successive trials, Kristjánsson, Vuilleumier, Husain, Malhotra, and Driver (2005) demonstrated that neglect patients were sensitive to spatial priming for position, but only if they had an unlimited amount of time to respond (see also Geng & Behrmann, 2002). Similarly, Shaqiri and Anderson (2012) showed that a chronic neglect patient was able to benefit from the statistical structure of target locations to improve his performance toward the neglected side when he was exposed to regularities over a long period of time (3 days, Shaqiri & Anderson, 2012).

Together, these studies suggest that some forms of implicit processes can promote attentional orienting toward the left side in neglect patients in the absence of explicit awareness of the related contingencies. However, these findings are based on the use of relatively simple experimental designs, far from those encountered in the literature on implicit learning (Cleeremans, Destrebecqz, & Boyer, 1998). The paradigms generally used in implicit learning studies involve exposure to some complex rule-governed environment, such as a finite-state grammar, a deterministic spatial sequence, or a dynamic system (Cleeremans & Dienes, 2008). In addition, the absence of verbal report observed in studies involving neglect patients does not necessarily mean that explicit processes were not involved during learning; it could be that the patients were not confident enough in their knowledge to report it verbally (see Perruchet & Vinter, 2002; Shanks, 2003). Other measures, such as generation tasks, must be used in addition to the questionnaire to better characterize the nature (implicit vs. explicit) of the acquired knowledge.

The objective of the present study was twofold: (1) to explore the ability of neglect patients to implicitly learn complex conditional associations between stimuli, using tasks that are closer to those usually employed in the implicit learning literature; (2) to determine whether knowledge of these conditional associations would help them to respond to stimuli located in their neglected side. For this purpose, given the difficulty of applying the classical serial reaction time (SRT) task in neglect patients, we developed a new paradigm, an adapted SRT task, in which sequences of letters presented at the center of the screen are predictive (or non-predictive) of the target location (see Section 2 for details).

More specifically, we investigated neglect patients' ability to use the predictive letters to orient faster toward the left and to increase their rate of detection of left targets. If participants learn about associations between letters and target location, this should produce a facilitation effect for targets following predictive letters compared with non-predictive letters over time. We expected the facilitation effect to be particularly clear at the end of the learning task, i.e., in the last block.