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Escaping capture: Bilingualism modulates distraction from working memory

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ABSTRACT

We ask whether bilingualism aids cognitive control over the inadvertent guidance of visual attention from working memory and from bottom-up cueing. We compare highly-proficient Catalan–Spanish bilinguals with Spanish monolinguals in three visual search conditions. In the working memory (WM) condition, attention was driven in a top-down fashion by irrelevant objects held in WM. In the Identify condition, attention was driven in a bottom-up fashion by visual priming. In the Singleton condition, attention was driven in a bottom-up fashion by including a unique distracting object in the search array. The results showed that bilinguals were overall faster than monolinguals in the three conditions, replicating previous findings that bilinguals can be more efficient than monolinguals in the deployment of attention. Interestingly, bilinguals were less captured by irrelevant information held in WM but were equally affected by visual priming and unique singletons in the search displays. These observations suggest that bilingualism aids top-down WM-mediated guidance of attention, facilitating processes that keep separate representations in WM from representations that guide visual attention. In contrast, bottom-up attentional capture by salient yet unrelated input operates similarly in bilinguals and monolinguals.

1. Introduction

It has been repeatedly shown that bilingualism has an impact on cognitive control mechanisms required to resolve conflicting responses to stimuli – as in Stroop-like tasks (e.g. Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Hernández, Costa, Fuentes, Vivas, & Sebastián-Gallés, 2010; Martin-Rhee & Bialystok, 2008). This impact has been indexed by two effects. First, conflict effects produced by incongruent information are larger for monolinguals than for bilinguals (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Costa et al., 2008, 2009; Hernández, Costa, Fuentes, et al., 2010; Hernández, Costa, & Humphreys, 2010). Reduced conflict effects have been taken as evidence that bilingualism could benefit inhibitory mechanisms required to overcome conflicting information. Second, bilinguals are overall faster than monolinguals (e.g., Bialystok, 2006; Costa et al., 2008, 2009; Martin-Rhee & Bialystok, 2008). This observation has been interpreted as evidence that bilinguals are more efficient at adjusting behaviour according to the current demands. Thus, in the case of tasks involving conflicting information, bilinguals can alternate more easily than monolinguals

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between trials that require conflict resolution and those that are free of conflict (see Costa et al., 2009).

These bilingual advantages have been associated with the use of control mechanisms that prevent linguistic interference during bilingual language processing. Although the specific language control mechanisms at play are still under debate [inhibition of the unintended language (e.g. Green, 1998) vs. selection of the intended language (e.g. Costa, Santesteban, & Ivanova, 2006)], it has been argued that these mechanisms partially overlap, functionally and anatomically, with general cognitive control mechanisms (Abutalebi & Green, 2007, 2008). As a result of this, bilinguals may engage general mechanisms of cognitive control (e.g., inhibitory processes, task monitoring) more frequently than monolinguals, giving rise to the bilingual advantage in control processes.

Recent studies have extended the bilingual advantage to other cognitive control processes that do not seem to involve conflict resolution, such as dual modality monitoring (Bialystok, Craik, & Ruocco, 2006), reactive inhibition (Colzato et al., 2008), and task-switching (Prior & MacWhinney, 2010). These findings raise the question of the boundaries for the effects of bilingualism on general-domain cognitive control.

In the present study we explored these boundary conditions by examining the effects of bilingualism on particular bottom-up and top-down factors that modulate visual search. In the remains of the Introduction, we provide a description of the top-down and bottom-up phenomena of attentional guidance, followed by our predictions on the impact that bilingualism would have on them.

1.1. Top-down and bottom-up factors guiding visual attention

The ability to guide attention to a target object can be affected by distracting stimuli that are either highly salient relative to the other elements present (bottom-up guidance; e.g. Theeuwes, 1991, 1992; Theeuwes, de Vries, & Godijn, 2003) or that match items held in working memory (WM) (top-down guidance; e.g. Downing, 2000; Soto, Heinke, Humphreys, & Blanco, 2005; Soto & Humphreys, 2009). For example, when driving your car, your attention can be captured by signals indicating certain directions with similar names to the one you have in mind (top-down guidance). However, your attention is also captured by salient stimuli such as the sound of an ambulance or the red lights indicating sudden braking of the car just in front of you (bottom-up guidance).

Experimental studies of bottom-up guidance of attention have often used the phenomenon of singleton capture. As example of this task, and highly relevant for our study, Theeuwes et al. (2003) found that visual search is disrupted by the concurrent presence of distracting stimuli that are unique in some irrelevant dimensions (i.e. singletons). In these Singleton paradigms, participants are presented with a search display composed of coloured geometrical figures, each containing a line. All lines are totally straight (distracters), except for one that is slightly tilted towards the left or the right (the target). Participants' task consists in looking for the tilted line and indicating its direction via button press (right or left), as fast as possible. That is, the shapes and colours of the geometrical figures are completely irrelevant for the task at hand, and participants only have to ignore them. The crucial aspect of this paradigm is the inclusion of so-called singletons, namely a figure that outstands among the rest in the display. Neither the shape nor the colour of this singleton figure is repeated in any other figure, which makes the singleton perceptually salient in the display search (see Fig. 1C in Section 2 for a schematic illustration of the Singleton version of our paradigm). The perceptual saliency of the singleton makes it hard for participants to prevent this item from capturing attention during visual search. In fact, performance is facilitated (Singleton benefit) when the target line falls within the singleton figure, and disrupted (Singleton cost) when the target line falls within any other figure of the display (relative to a neutral condition where no singleton figure is present in the search display).

Effects of top-down guidance have been demonstrated in studies examining how information actively maintained in WM affects attentional guidance. Soto et al. (2005) found that visual search performance is affected by the concurrent presence of distracters that match the contents of stimuli held (WM). As in Singleton paradigms, Soto et al.'s participants were instructed to look for the tilted line (target) among all the lines inside each coloured geometrical figure in the search display. Prior to be presented with the search display, however, participants had to memorize a coloured figure (the cue) and maintain it in WM for a memory test, which came immediately after the visual search task. That is, participants were first presented with a to-be-memorized cue. Then, the search display appeared and they had to search for the tilted line. Subsequently, participants were presented with a single figure and asked whether it matched both the colour and shape as the cue they were keeping in WM.

The crucial manipulation is whether the target line falls within an irrelevant coloured figure that corresponds to the cue kept in WM. If the cue kept in WM contains the target line, performance is facilitated (a WM benefit); however if the cue does not contain the target line then performance is disrupted (a WM cost) (performance is in both cases compared against a neutral condition in which the cue held in WM is not present in the search display) (see Fig. 1A in Section 2 for a schematic illustration of the WM version of our paradigm).

Importantly, these effects are very much reduced when the cue presented prior to the visual search display does not need to be kept in WM. In the so-called Identify paradigm, participants are presented with exactly the same cues and search displays as in the WM paradigm, but they are not asked to keep the cue in WM. For example, they may be asked to compare the colour and shape of two initial visual cues presented consecutively within a short period of time. The search task is carried out if the cues match (as in the WM condition), otherwise no response is made (e.g., Soto & Humphreys, 2009; Soto, Humphreys, & Rotshtein, 2007; Soto et al., 2005) (see Fig. 1B in Section 2 for a schematic illustration of the Identify version of our paradigm).

Since the effects of the cue are greater in the WM paradigm compared with the Identify paradigm, it can be