Consciousness and Cognition 29 (2014) 212–229

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Introspection during visual search

Gabriel Reyes [a,b,*], Jérôme Sackur [a,c,*]

[a] Laboratoire de sciences cognitives et psycholinguistique, CNRS/EHESS/ENS, Paris, France
[b] Université Pierre et Marie Curie, Paris, France
[c] Institut Universitaire de France, Paris, France

ARTICLE INFO

Article history:
Received 27 April 2014
Available online 3 October 2014

Keywords:
Introspection
Perceptual decision
Cognitive processes
Consciousness
Metacognition

ABSTRACT

Recent advances in the field of metacognition have shown that human participants are introspectively aware of many different cognitive states, such as confidence in a decision. Here we set out to expand the range of experimental introspection by asking whether participants could access, through pure mental monitoring, the nature of the cognitive processes that underlie two visual search tasks: an effortless "pop-out" search, and a difficult, effortful, conjunction search. To this aim, in addition to traditional first order performance measures, we instructed participants to give, on a trial-by-trial basis, an estimate of the number of items scanned before a decision was reached. By controlling response times and eye movements, we assessed the contribution of self-observation of behavior in these subjective estimates. Results showed that introspection is a flexible mechanism and that pure mental monitoring of cognitive processes is possible in elementary tasks.

1. Introduction

Humans are endowed with introspection, the ability to monitor their own mind. For a long period in the history of experimental psychology this ability was viewed with some suspicion, mainly because introspection as a method for the investigation of cognitive functioning was largely unsuccessful (see a review in Boring, 1953; Costall, 2006; Danziger, 1980; Lyons, 1986; Sackur, 2009). However, since the recent re-conceptualization of introspection as an intrinsic feature of consciousness (Feest, 2012; Goldman, 2004; Piccinini, 2003), it has been reconsidered as a legitimate field in cognitive psychology (Jack & Shallice, 2001; Schooler, 2002; Schooler & Schreiber, 2004) and amenable to experimentation in neuroscience (Baird, Smallwood, Gorgolewski, & Margulies, 2013; Fleming & Dolan, 2012; Fleming, Weil, Nagy, Dolan, & Rees, 2010; Jack & Roepstorff, 2002).

Despite great progress in the science of introspection in recent years, an issue not yet resolved is: what mental content is accessible to introspection? In the wake of Nisbett and Wilson's seminal paper (Nisbett & Wilson, 1977), researchers have been very wary of the kinds of introspective reports they should elicit from their participants. Nisbett and Wilson gathered considerable empirical evidence and theoretical arguments to the effect that one should clearly distinguish reports on internal cognitive *states* as opposed to internal cognitive *processes*. While the former may, in some context, be introspectively accessed, the latter were deemed, by and large, inaccessible. Thus, asking participants about them would most often lead to confabulations. Nisbett and Wilson held that the process that links a stimulus and the response does not reach participants' consciousness, and that only cognitive products or states are consciously accessed (see also Neisser, 1967). Despite

* Address: Laboratoire de Sciences Cognitives et Psycholinguistique, École Normale Supérieure, 29 rue d'Ulm, 75005 Paris, France.
E-mail addresses: gureyes@uc.cl (G. Reyes), jerome.sackur@gmail.com (J. Sackur).

http://dx.doi.org/10.1016/j.concog.2014.08.009
1053-8100/

initial substantial objections (Ericsson & Simon, 1980; Smith & Miller, 1978; White, 1980, 1987, 1988), and recent reformulations (Wilson, 2002, 2003), this idea is considered as a canon of the literature on metacognition (Johansson, Hall, Silkström, & Olsson, 2005; Overgaard, 2006; Overgaard & Sandberg, 2012).

In recent years, the set of responses that may qualify as introspective has considerably increased. Among these, traditional confidence ratings (e.g., Fleming et al., 2010; Pleskac & Busemeyer, 2010; Song et al., 2011) have been reconsidered in depth, and new ones, such as judgments of duration of perceptual decisions (Corallo, Sackur, Dehaene, & Sigman, 2008; Marti, Sackur, Sigman, & Dehaene, 2010; Miller, Vieweg, Kruize, & McLea, 2010) have come to the fore. However, it is important to note that all these new forms of introspection are reports on internal cognitive *states*, and thus all abide by Nisbett and Wilson's canon. In this paper, we seek to put this limitation under experimental scrutiny.

It is interesting to note that most cognitive processes that Nisbett and Wilson target are complex, high-level forms of reasoning. Recent advances in the field of introspection have all been achieved by focusing on elementary cognitive tasks. For instance, Corallo et al. (2008) and Marti et al. (2010) selected the well-studied *Psychological Refractory Period* paradigm, as a first order cognitive task, and asked participants to report the durations that they introspectively perceived while performing this task. Here, we ask whether participants are introspectively aware of a difference in the kinds of processes triggered by two well-attested first order experimental tasks.

We relied on the following basic paradigm: we instructed participants to perform a visual search task in two different conditions, one simple and fast, in which the target "pops out", the other being more difficult and requiring an effortful exploration of the visual scene. Concurrently, on a trial-by-trial basis, we collected quantitative introspective reports. Our aim was to assess whether these introspective reports correlated with differences in processing that we could infer from a third-person, external standpoint. We chose visual search as a first order task, as it is known that in this task minimal changes in the stimuli induce important changes in performance profiles, indicative of a switch between two modes of processing. Traditionally, searches were construed as either *parallel* or *serial* processes (Sternberg, 1966; Townsend, 1990). In visual search, Treisman's seminal Feature Integration Theory (FIT, Treisman & Gelade, 1980) contrasted *feature searches* and *conjunction searches*, the former producing parallel searches and the latter serial searches. This difference was meant to account for the empirical finding that in feature searches, mean Response Times (RTs) do not increase as the number of distractors is increased, while in conjunction searches, mean RTs increase linearly as a function of the number of distractors. FIT asserts that in feature searches the visual system extracts in parallel, pre-attentively, the set of basic characteristics of the scene, which are necessary and sufficient to select the response. On the contrary, in *conjunction searches* attention is deployed serially one item, or group of items, at a time.

A strict dichotomy between parallel and serial searches is no longer tenable (Eckstein, 2011). First, it has been known for a long time that linear increase in mean RTs is not diagnostic of serial processing (*model mimicking*, Townsend & Wenger, 2004). Second, it appeared that there is a continuum of more or less efficient searches (Thornton & Gilden, 2007; Wolfe, 1994, 2007; Wolfe, Cave, & Franzel, 1989). The current consensus is that inefficient visual searches exhibit prominently *capacity limits*, whereas efficient searches do not incur such limits. Furthermore, it is also widely admitted that easy, efficient searches evade capacity limits because they benefit from *guidance of attention* by features extracted from non-selective pathways (Wolfe, 2003; Wolfe & Horowitz, 2004; Wolfe, Võ, Evans, & Greene, 2011, but see Cameron, Tai, Eckstein, & Carrasco, 2004; McElree & Carrasco, 1999). Our objective was to test whether participants can introspectively access the presence or absence of capacity limits and of attentional guidance.

Of course, no decision process is ever absolutely without "capacity limits", and visual searches are no exception to this rule. For instance, Joseph, Chun, and Nakayama (1997) showed that even highly efficient pop-out searches are subject to capacity limits when performed in conjunction with an attention depleting dual task. This feature is nicely accounted for by dual stage models of visual search (Wolfe, 2003) where the second, response selection stage is viewed as a central decision stage, subject to bottleneck effects. The key point for us is that, in the absence of concurrent tasks, in efficient searches the response selection stage can benefit from parallel feature extraction performed during the first stage, through attentional guidance. Inefficient searches cannot benefit from attentional guidance, and thus always exhibit bottleneck effects that result in slower RTs with increasing set-size.

In all our experiments distractors were schematic Ts, while targets were either an X or an L. These stimuli are known to produce two clearly different search profiles. Without theoretical commitments, we will refer to searches of an X among Ts as Feature Searches (FS, targets defined by a single orientation feature), and to searches of an L among Ts as Conjunction Searches (CS, targets defined by the specific conjunction of two features that are also present in the distractors). After each decision on the search task, participants were instructed to report the number of items that they had scanned before giving their response, a measure that we termed "Subjective Number of Scanned Items" (SNSI). We predicted that participants' estimations would be constant and close to one item in FS, independently of the number of distractors on the screen. In contrast, we predicted higher SNSI scores in CS, and crucially, an increase as a function of set-size. One may think of this measure as the subjective counterpart to the "scanning process" of Sternberg's (1966) pioneering work on memory search.

Two important aspects of the SNSI measure should be emphasized here: first, this measure is an *index* of putative differences in processing. We did not ask our participants to report directly on the type of processes involved in a particular trial, but we reasoned that if there were any such introspectively accessible differences, they should show in the number of subjectively scanned items before the decision. Second, we expect our index to be analytical or pure (Sternberg, 2001), to the extent that it captures only one among presumably many different kinds of introspective information. That is, our SNSI index