Insights into the processes underlying the early fixation-based memory effect

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ABSTRACT

Previous research has shown that already durations of second fixations reveal concealed knowledge of an object. This very early memory effect could potentially be useful in applied settings. However, in order to use this effect, it is necessary to understand the processes causing the early fixation-based memory effect and the context which is necessary to obtain the effect. In four experiments, we disentangled the contribution of a probability-sensitive orienting response (OR) from probability-insensitive recognition memory processes. The results showed that the early fixation-based memory effect only appeared if both processes were involved. Moreover, the feature that triggers the OR has to be task relevant.

CCS CONCEPTS

• Applied computing • Law, social and behavioral sciences • Psychology

KEYWORDS

Fixation duration, concealed information, orienting response, recognition memory processes

1 Introduction

In many settings, indirect measures (e.g., of attitudes or memories) represent the possibility to get access to information that is potentially inaccessible in a direct way. This can be the case when it is not possible to communicate due to severe health impairments (e.g., locked-in patients) or the developmental age (infants), or when respondents are not willing to inform about the demanded information. With respect to the latter case, past research has shown that eye movements could be useful to reveal item knowledge despite the deliberate concealment of that knowledge in explicit communication [see Lancry-Dayan et al, 2018; Millen et al, 2017; Nahari et al, 2019; Peth et al, 2013; Schwedes & Wentura 2012; 2016]. A common paradigm used to reveal concealed knowledge is the concealed information test (CIT).

1.1 The CIT

In a CIT, participants are typically confronted with three different kinds of stimuli: crime-related probes (i.e., stimuli known by persons with crime knowledge), known but not crime-related targets (i.e., stimuli participants get familiar with as part of the CIT), and unknown irrelevant items. The ratio between targets, probes, and irrelevant items is typically 1:1:4. In the CIT, participants have to make target/non-target decisions (e.g., by button press) on each item trial-by-trial. For participants without crime knowledge this is a simple task of discriminating between known (i.e., the targets) and unknown (i.e., probes and irrelevant items) stimuli. However, participants with crime knowledge must discriminate within the set of known items to respond correctly. The basic assumption of the CIT is that crime knowledge causes a different response pattern to probe and irrelevant items in indirect measures, the CIT-effect, whereas participants without crime knowledge should show the same response pattern to probe and irrelevant items. Using fixation durations as the dependent variable in a CIT, Schwedes and Wentura [2012; 2016] showed prolonged durations of second fixations to probes compared to irrelevant items (for participants who knew the probes), that is, the authors found a CIT-effect within the first second of item inspection. To maximize the validity of the effect and therefore the usefulness of this very early memory effect for applied settings, it is necessary to understand the underlying processes and which settings are necessary to observe the effect.

1.2 Mechanisms underlying the CIT-effect

Regarding the underling processes of the CIT-effect, one common assumption is that probes evoke an orienting response (OR) for participants with crime knowledge due to their rare occurrence (e.g., Verschuere et al, 2004; see Verschuere & Ben-Shakhar, 2011; Verschuere & De Houwer, 2011, for a review). The OR is described as a conglomerate of behavioral and physiological responses to a novel, rare, or personally relevant stimulus that attracts attention [Sokolov, 1963]. For participants with crime knowledge it is assumed that this OR triggers, for example, a change in physiological measures (such as heartrate deceleration, respiratory suppression, and skin conductance increase [Gamer, 2011], prolonged reaction times [Verschuere & De Houwer, 2011], or an increased P300, a positivity around 250-500 ms post stimulus onset at the midline of frontal to parietal EEG electrodes [Rosenfeld, 2011]. However, other authors discuss memory processes as possible mechanisms underlying the CIT-effect [Bergström et al., 2013; Schwedes & Wentura, 2012, 2016; Seymour & Schumacher, 2009; Seymour & Seifert, 1998]. For example, Bergström and colleagues (2013) showed that the P300-based CIT-effect is not only due to an OR but also due to episodic recollection. Regarding the fixation-based CIT-effect (i.e., longer second fixations to probes compared to irrelevant items [Schwedes & Wentura, 2012, 2016], we assume that both types of processes, a probability-sensitive OR and a probability-insensitive recollection process, might be involved. Recollection, i.e., memory for episodic details, is presumed to contribute to the effect because participants with crime knowledge have to discriminate between target and probe items to respond in the instructed way. Discrimination between two types of known items requires recollection and second fixations are especially relevant for item recollection [Schwedes, Scherer & Wentura, 2019; Schwedes & Wentura, 2019].

1.3 Overview

The goal of the present study was to get insights in the processes that cause prolonged second fixations to concealed knowledge, since this very early memory effect could potentially be useful in applied settings. However, in order to use this effect as an indirect measure of memory, it is necessary to understand the processes causing the early fixation-based memory effect and the context which is necessary to obtain the effect. Due to the structure of a CIT, probe items are rarely presented items, a property that triggers an OR. In addition, the correct classification of probes as non-targets requires recollection for participants with crime knowledge. Therefore, the present study investigates the contribution of a probability-sensitive OR and probability-insensitive recognition memory processes to the early fixation-based CIT-effect. We conducted four experiments (albeit using one sample of participants) to disentangle the contribution of an OR and recognition memory processes to the prolonged durations of second fixations. Experiment 1 and 2 only included probes and irrelevant items. In Experiment 1, probe stimuli were rarely presented items as defined by the gender of the face. However, all items were unfamiliar. Thus, if the duration of second fixations will be different for probes and irrelevants, this effect must be due to a rarity-based OR. Experiment 2 had the same procedure as Experiment 1 with the exception that probes were also familiar. If the duration of second fixations will be different for probes and irrelevants, this effect can be triggered by an OR based on rarity and familiarity. Potential differences between Experiment 1 and 2 can be attributed to familiarity. In both experiments no target items were included. Thus, compared to a CIT, item familiarity was irrelevant for the participants' task. In Experiment 3 and 4, we replicated the CIT experiment by Schwedes and Wentura [2016], that is, probe items were known, they were presented intermixed with targets and irrelevants, and the task was to discriminate targets from probes/irrelevants (i.e., recollection was necessary to differentiate targets from probes). As all face stimuli were of the same gender, an OR could only be evoked by item familiarity. In Experiment 3, the ratio between probes and irrelevants was 1:4 whereas the ratio was changed to 1:2 in Experiment 4. This change eliminated the potential contribution of an OR (based on rareness of familiar items to the CIT-effect), since the ratio between familiar and unfamiliar items was 1:1 (probes and targets vs. neutral items). If a CIT-effect is found in Experiment 3 and 4, it can only be attributed to recollection and not to an OR. If Experiment 3 but not Experiment 4 yields a CIT-effect, an OR at least contributes to the effect. In this case, it depends on the outcome of Experiment 2 (rare and familiar probes, but no recollection necessary) whether a combination of OR and recollection is decisive or OR alone is the driving factor.

2 Method

2.1 Participants

Thirty undergraduate students from Saarland University took part in all experiments in a single session in exchange for course credit. The median age of the participants was 22.5 years (ranging from 18–35 years). All had normal or corrected-to-normal vision and were native speakers of German.

2.2 Material and Design

The basic design was 2 (Item Type: probe vs. irrelevant) × 2 (Fixation: first vs. second) for all experiments.

In Experiment 1 and 2, probes were rare (p = .2) compared to irrelevants (p = .8). Probes had the opposite gender compared to irrelevants (balanced across participants). In Experiment 2, probe items were not only rare but also familiar. A third task-relevant item category (targets) was added in Experiment 3 and 4. Now, all three item types had the same gender (i.e., either all female or all male). In total, the materials comprised 200 colored face images (100 men and 100 women) taken from the Glasgow Unfamiliar Face Database [Burton et al, 2010]. Experiment 1 and 2 contained 50 faces: 10 probes and 40 neutral items (10 irrelevants and 30 fillers; they were not distinguishable by participants). Experiment 3 contained 60 faces: 10 targets, 10 probes and 40 neutral items (10 irrelevants and 30 filler). The probability of neutral items was reduced in Experiment 4. It contained 40 faces: 10 targets, 10 probes and 20 neutral items (10 irrelevants and 10 filler). The order of the four experiments were the same for all participants. Materials were counterbalanced across participants such that each face appeared equally often as a probe and as an irrelevant stimulus in each experiment.

2.3 Apparatus

The eye movements of the participants' dominant eye were recorded with an SMI Hi-Speed Eye-Tracker with a sample rate of 500 Hz. A calibration was defined as valid if the spatial error was less than 1°. The default parameters for fixation detection of the recording software SMI BeGaze were used (maximal dispersion value was set to 100 pixels and the minimum fixation duration to 80 ms). Stimuli were presented with a Windows-based computer on a 24'' monitor with a resolution of 1920 × 1080 pixels and a refresh rate of 120 Hz, using the experimental software PsychoPy [Peirce, 2007]. The viewing distance measured 64 cm.

2.4 Procedure

All participants run through all four experiments (in the order Exp. 1 to Exp. 4). In Experiment 1 and 2, the participants' task was to rate the intelligence of the depicted person. After a 50 ms fixation cross, a face was presented for 3000 ms on the right or left side of the fixation cross. In this time, eye-movements were recorded. Then they were prompted to rate the face with respect to its assumed intelligence (above-average, average, below-average). Then the next trial started. In Experiment 2, this phase was preceded by a familiarization phase in which participants were presented with ten faces that served as probes. The ten faces were presented trial by trial for 3000 ms and participants were instructed to memorize these faces.

In Experiment 3 and 4, participants were familiarized with two groups of faces, their "friends" (later used as probe items) and their "foes" (later used as target items). To make sure that participants were able to differentiate between "friends" and "foes", this phase ended with a short test in which participants had to indicate for each face whether it is a "friend" or a "foe". At the beginning of the CIT, participants were instructed that their friends and foes were involved in fisticuffs and that they are now at a police station to serve as a witness to identify the persons involved. They were also instructed to protect their friends from being accused but to identify the foes. A trial started with a central fixation cross after which a face appeared on the left or right side of the cross for 3000 ms. During this time eye-movements were recorded. Then the face disappeared and they were prompted to make an "involved" (for targets/foes) versus "not involved" (for all other faces) decision by pressing on the corresponding button.

3 Results

As outlined, the present experiments are follow-ups to previous studies [Schwedes & Wentura, 2012, 2016] that established a CIT effect in the duration of second fixations. Therefore, the analyses focus on first (as a control) and second fixation. The mean fixation durations as a function of fixation (first vs. second) and stimulus type (probe vs irrelevant) are depicted in Fig. 1.

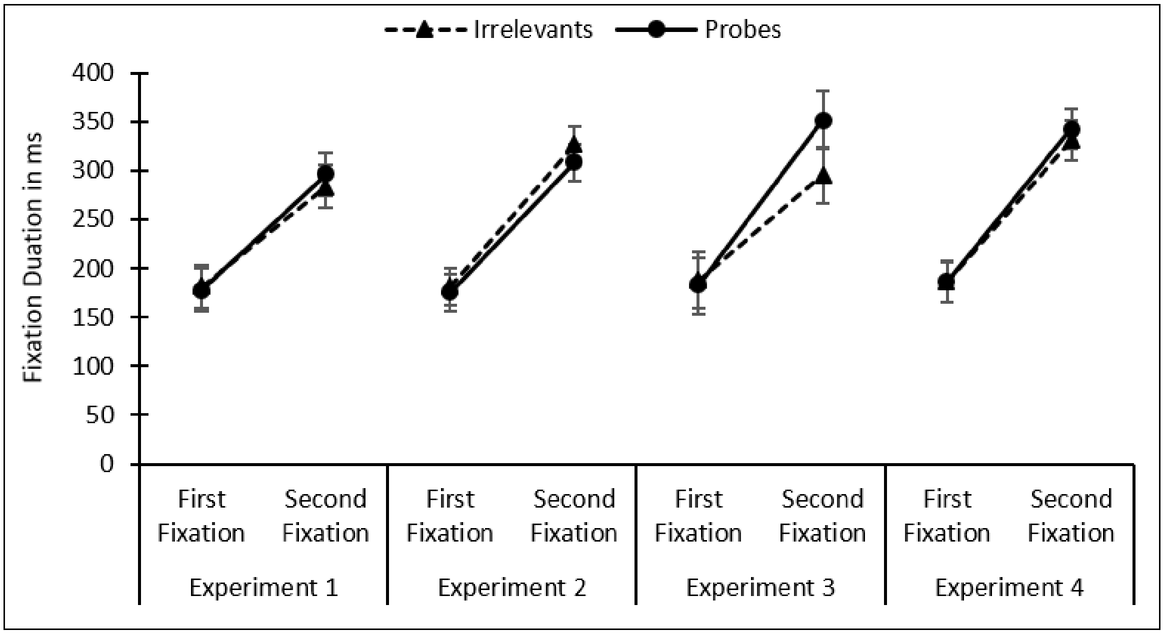

Figure 1: Fixation duration (in ms) for the first two fixations as a function of item type and experiment. Error bars are 95 % within-subject confidence intervals [Jarmasz & Hollands, 2009] for the Fixation (first versus second) × Item Type (probes versus irrelevants) interaction.

For each experiment, we conducted a 2 (Fixation: first vs. second) × 2 (Item Type: probe vs irrelevant) ANOVA for repeated measures with fixation duration as the dependent variable. For Experiment 1 and 2, only the main effect of fixation was significant, $F(1,29) = 39.25$, $p < .001$, $\eta_p^2 = .575$ for Experiment 1 and $F(1,29) = 25.00$, $p < .001$, $\eta_p^2 = .463$ for Experiment 2, indicating that second fixations lasted longer than first fixations. All other effects were non-significant, F's < 1, p's >.445 for Experiment 1 and F's < 1.61, p's > .214 for Experiment 2.

In Experiment 3, the effect of fixation, $F(1,29) = 43.45$, $p < .001$, $\eta_p^2 = .600$, as well as the interaction effect, $F(1,29) = 4.77$, $p = .037$, $\eta_p^2 = .141$, were significant. As predicted, no difference appeared between probes and irrelevants in the duration of first fixations, $t(29) = -0.96$, $p = .345$. However, second fixations were longer for probes compared to irrelevants, $t(29) = 1.88$, $p = .035$ (one-tailed), $d_z = .343$, replicating the fixation-based CIT-effect. In Experiment 4, again only the main effect of fixation was significant, $F(1,29) = 34.21$, $p < .001$, $\eta_p^2 = .541$. All other effects were non-significant, F's < 1, p's >.541.

4 Discussion

With four experiments, we investigated the contribution of a probability-sensitive orienting response (OR) and probability-insensitive recognition memory processes to the early fixation-based CIT-effect. Under conditions that only involve an OR without any memory processes (Experiment 1), fixation durations were not affected by item type. In addition, the strengthening of an OR by a probe that was not only from the rare gender category but also familiar did not result in prolonged fixation durations. In these experiments, gender and familiarity of an item was not task-relevant (Experiment 2). When probes were rarely presented familiar items and the task required recollection because participants had to discriminate probes from familiar targets (Experiment 3), we replicated the CIT-effect. The duration of second fixations were prolonged for probes compared to irrelevant items. If, however, the contribution of an OR based on rare familiarity was eliminated, due to a balanced number of familiar and unfamiliar items, the effect disappeared (Experiment 4).

The results of Experiment 1 and 4 suggest that both processes, the probability-sensitive OR and probability-insensitive recognition memory processes, cannot affect fixation durations independently. Comparison of Experiment 2 and 3 indicates that the OR evoked by item familiarity leads only to prolonged fixation durations if item familiarity is task relevant. Finally, the absence of the fixation effect in Experiment 4 suggests that it is not the recollection process per se that causes the CIT-effect.

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