Acta Psychologica 179 (2017) 54–60

Contents lists available at ScienceDirect

Acta Psychologica

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

Associative cueing of attention through implicit feature-location binding

Giovanna Girardi*, Daniele Nico

Department of Psychology, University Sapienza of Rome, Rome, Italy

A R T I C L E I N F O

Keywords:
Associative learning
Selective attention
Working memory
Spatial cueing
Multisensory integration

A B S T R A C T

In order to assess associative learning between two task-irrelevant features in cueing spatial attention, we devised a task in which participants have to make an identity comparison between two sequential visual stimuli. Unbeknownst to them, location of the second stimulus could be predicted by the colour of the first or a concurrent sound. Albeit unnecessary to perform the identity-matching judgment the predictive features thus provided an arbitrary association favouring the spatial anticipation of the second stimulus. A significant advantage was found with faster responses at predicted compared to non-predicted locations. Results clearly demonstrated an associative cueing of attention via a second-order arbitrary feature/location association but with a substantial discrepancy depending on the sensory modality of the predictive feature. With colour as predictive feature, significant advantages emerged only after the completion of three blocks of trials. On the contrary, sound affected responses from the first block of trials and significant advantages were manifest from the beginning of the second. The possible mechanisms underlying the associative cueing of attention in both conditions are discussed.

1. Introduction

Our environment continuously provides an amount of stimuli dramatically exceeding the brain's cognitive resources. While this redundancy of information is automatically processed by the sensory systems, only a relatively small fraction reaches awareness. Because of its limited capacity, the brain must select and prioritize incoming information according to individual expectancies and motivations. Hence, a fundamental part of our cognitive repertoire is the ability to select environmental information, and modulate sensorial access in favour of those stimuli whose physical properties, or locations, specifically fall under the focus of attention (Nobre & Mesulam, 2014). Experimentally, voluntary attentional control has been extensively studied via cueing and visual search experiments in which participants informed about the likely location/dimension of an upcoming task-relevant (i.e., to be reported) target are faster to respond if the latter does in fact appear in the expected location/dimension (see Driver, 2001 for a review). In this sense, attention is endogenously regulated through a central, top-down cognitive mechanism.

Of course, a similar mechanism would be disadvantageous should selective attention result in blocked access for all task-irrelevant target dimensions. Switching-off the environment while paying attention only to selected features would mean interrupting the natural flow of information, reducing reality to a sequence of frames reflecting the tasks the brain focuses on. Actually, task-irrelevant target features with particular salience can access the cognitive system even when attention is selectively engaged elsewhere showing that the brain filters – rather than blocking – irrelevant information. The literature is rife of examples demonstrating that individuals may automatically develop attentional priorities for one task-irrelevant feature dimension that co-occur with the attended one suggesting that there are intermediate forms of attentional control driven by memory, experience, reward, and/or implicit learning, including incidental associations (Awh, Belopolsky, & Theeuwes, 2012).

However, our sensory environment contains also complex regularities that can co-occur among apparently distant elements. For example, the appearance of the stop signal for pedestrian crossing raises the expectancy of the green light for the driver waiting in her/his car at the traffic light. When a similar association is found, attention drifts to these predictive relational features that receive a higher top-down priority in the process of information selection (Chun & Turk-Browne, 2008; Kok, Rahnev, Jehee, Lau, & de Lange, 2012; Xu, 2010). Several studies have provided evidence that basic relationships can drive attention shifts when a single task-irrelevant feature co-occurs with the task-relevant target dimension (e.g., Kristjánsson, 2006; Kristjánsson, Mackeben, & Nakayama, 2001; Lambert, Naikar, McLachlan, & Aitken, 1999). To date, it remains unclear whether higher-order regularities between two (or more) task-irrelevant target dimensions can undergo some level of analysis and yield memory activations able to affect attentional control.

In a visual discrimination task with implicit cueing for target location

* Corresponding author at: Department of Psychology, Sapienza University of Rome, via dei Marsi n. 78, 00185 Rome, Italy.
E-mail address: giovanna.girardi@uniroma1.it (G. Girardi).

http://dx.doi.org/10.1016/j.actpsy.2017.07.006
Received 22 February 2017; Received in revised form 3 July 2017; Accepted 11 July 2017
Available online 14 July 2017
0001-6918/

Kristjánsson and Nakayama (2003) addressed this issue. They showed that whereas a simple one-step association between a feature (colour or shape) of a spatial cue and the target could be easily learned, a two-step contingency could not. In particular, evidence for learning was found only in cases where the target appeared within a part of the cue including a feature presented regularly in each trial, such as a given colour or a certain shape (see Experiments 1 and 2 in Kristjánsson & Nakayama, 2003). For instance, when the target appeared more and more often in a row of trials on the cue's green coloured part, discrimination significantly improved. However, when the whole of the cue was of a single colour that varied from trial to trial discrimination did not improve. Namely, learning occurred for simple, direct associations that are constantly available in a set, but not for cases requiring a two-step inference (e.g. "if a certain colour is present, then the target will appear at a given location", see Experiments 3 & 4 in Kristjánsson & Nakayama, 2003).

It should be noted however that in that study both cue lead and target times were very brief (by 50–200 msec), and were also followed by a masking stimulus. A similar set-up may well justify why the two-step, higher order relationship between cue and target failed in producing tangible effects. Actually, the direct association between a salient location (i.e., indexed by a specific stable feature such as colour or shape) and target appearance could be explained by a sort of basic sensorial facilitation (or "transient attention", according to authors). On the contrary, the second-order association remained undetected since no expectancy was allowed due to the temporal constraints preventing the corresponding cognitive processing.

Many studies have shown that implicit attentional shifts can, in fact, be modulated by the expectancies of the observer or her/his prior experience (e.g., Chun & Jiang, 1998; Fecteau & Munoz, 2003; Fiser & Aslin, 2001; Geng & Behrmann, 2005; Girardi, Antonucci, & Nico, 2013; Turk-Browne, Jùnge, & Scholl, 2005; Vatterott & Vecera, 2012). Thus, the degree to which relational features break through attentional filters may be dependent on how relevant they are to the task at hand (Gozli, Moskowitz, & Pratt, 2014). According to Gozli et al. (2014), task-irrelevant dimensions can be implicitly processed when they are associated with a task-relevant dimension. In an initial acquisition phase, participants learned two distinct sequences of stimuli (shapes)/responses (localized key-presses)/outcomes (colours). Results in the later testing session showed that informing participants about the probable shape biased them toward the colour associated with it. Co-occurrences between a task-relevant feature (shape) and a task-irrelevant feature (colour) could then be learned. The authors concluded that such a second-order associative learning could emerge only because colours were not entirely task-irrelevant being associated to significant target features (shapes).

More recently, Nico and Daprati (2015) extended this result showing that co-occurrences between two task-irrelevant dimensions could also be learned when a high behavioural salience was present. In three experiments, two visual stimuli were presented in a sequence. Participants had to discriminate the shape of the second stimulus (the target) while ignoring the first. Unbeknownst to them, target's location was highly predictable (i.e., 100%) from the colour of the first stimulus or the pitch of a tone associated to it. Thus, a task-irrelevant dimension (i.e., location) was implicitly predicted by another task-irrelevant dimension. Responses were faster when the target appeared in the non-predicted location (Experiments 1 & 2), showing that the implicit association was detected, even if it did not lead to a facilitation for implicitly cued trials. The "selective disadvantage" of cued trials was reversed by an uninformative alerting tone associated with the first stimulus that again cued the location with its colour (Experiment 3). In this case, the representation of the irrelevant feature mediating the implicit association was made "active" because of the tone-induced salience and by driving attention on the first stimulus allowed a prior visual entry (Theeuwes & Van der Burg, 2013; Van der Burg, Olivers, Bronkhorst, & Theeuwes, 2008). The spatial advantage produced by the alerting tone seems then to imply the possibility that a stimulus must actively consolidate into working memory before an effect of attentional control could take place (Downing, 2000; Soto, Humphreys, & Heinke, 2006). Even if suggestive of the possibility that second-order associations can influence attentional control, these results are not conclusive for several reasons. For instance, it remains unclear why, in Experiment 2, the informative tone did not exert its alerting potential on the first stimulus to prioritize its access. Moreover, while irrelevant for the task, in all experiments the first stimulus had the role of a response prime since its shape always matched one of the possible targets. The presence of a prime in the task was demanding and asked for cognitive control and attentional resources to avoid errors in responding. In this sense, the priming task-set was prioritized over the second-order association (which was a target-irrelevant dimension). Consistent with this explanation, when attention is drawn by an alerting sound the shape priming effects decrease, being stronger in Experiment 1 as compared to Experiment 3 (see Nico & Daprati, 2015).

To sum up, evidence so far demonstrates that higher-order regularities between two task-irrelevant target dimensions can be implicitly learned. However, as the participants' attention is directed on the primary task, for instance target shape discrimination, task-irrelevant relational features can by-pass the filter of attention only in two possible conditions: when they are linked to a task-relevant dimension and long-term experience is allowed (Gozli et al., 2014), or when they have some behavioural salience promoting prior entry (Nico & Daprati, 2015). In both cases predictive features that reliably predict target location need to receive some degree of attention in order to affect behaviour. Being attention the crucial factor it can be expected that having attentional resources available at the moment of stimulus encoding should maximize associative learning. A way to increase the attentional load while participants are engaged in a task is asking them to actively maintain stimulus representation in visual working memory. This typically occurs when participants have to hold the stimulus features in order to report them at a later moment (Soto et al., 2006).

In the present study, we used an identity-matching task between two consecutive shapes tapping on visual working memory to form an active template necessary for the perceptual judgment. This template is expected to include all the features associated to the target even if they are not directly related to the response. As a consequence, the association between an arbitrary feature of the first stimulus and the spatial location of the second should be made available to the cognitive system. We then assume that including such a working memory component would be sufficient to tune participants' attention to process predictive regularities between two task-irrelevant target dimensions.

To examine whether these implicit associations differently cue spatial attention depending on the salience of the task-irrelevant feature (see Nico & Daprati, 2015), we presented participants with unimodal (visual) or crossmodal (audiovisual) feature regularities.

2. Material and methods

2.1. Participants

Thirty-two students (age 24.19 ± 3.17, 16 males) volunteered for the experiment that was carried out according to the Declaration of Helsinki and was approved by the ethical committee of the Department of Psychology of the University Sapienza of Rome. They were randomly assigned to one of two experimental conditions that differed according to the sensory modality conveying the implicit spatial cue (unimodal and crossmodal condition). Sample size (n = 16) was determined using pilot experiments and based on a previous study (Nico & Daprati, 2015) investigating similar effects. All participants were naive as to the purpose of the experiment, had normal or corrected-to-normal vision and did not suffer from colour-blindness.

2.2. Stimuli and procedure

Participants rested their head on a chin-rest in front of a screen