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Stimulus-response links and the backward crosstalk effect — A comparison of forced- and free-choice tasks

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ABSTRACT

In dual-tasks, characteristics of Task 2 responses can already affect performance in the preceding Task 1. This is called the backward crosstalk effect (BCE). To account for the BCE, it has been suggested that the appearance of the Task 2 stimulus automatically projects activation onto the corresponding response through (transient or direct) stimulus-response (S-R) links. One way to investigate this claim is to compare the size of the BCE for tasks where S-R links are differently strong. To this end, we here compared BCEs for forced- vs. free-choice tasks, with the S-R links assumed to be stronger in the former than in the latter task. In Experiments 1 and 2, Task 1 was either forced-choice or free-choice and Task 2 always forced-choice, and in Experiment 3 this order was reversed. A BCE was observed in all experiments with the forced-choice tasks, but in response times it was smaller in Experiments 1 and 2 and absent in Experiment 3 with the free-choice task. However, in free-choice Task 1 responses, a bias towards selecting the response required in Task 2 was observed. These results suggest that the strength of S-R links plays a role in determining the size of the BCE. Relations to other studies and alternative explanations are discussed.

1. Introduction

In most if not all situations in everyday life humans engage in more than one task at the same time, that is, they are multitasking, and this is even true from early childhood on (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, 2015). In the laboratory, typically two tasks are combined to a dual-task, and a prevalent observation is that performance in one (or both) task(s) suffers in comparison to their isolated application as a single-task. Notably, particular characteristics of both tasks can also affect performance, and, most interestingly, characteristics of Task 2 can influence even the processing of the (first performed) Task 1. Such *backward crosstalk effects* (BCEs) suggest that response selection related processes of both tasks run (at least partly) in parallel. In the present study, we investigated the role of (instructed) stimulus-response links for the emergence and size of this effect.

1.1. Backward crosstalk in dual-task situations

When we perform two tasks concurrently, dual-task interference arises which usually means less than optimal performance in at least one or even both tasks as compared to a single-task situation. Central bottleneck models assume that pre-central perceptual and post-central motor stages can run in parallel with all stages of concurrently ongoing tasks, but that a central stage of response selection is responsible for the observed dual-task interference: only one central stage can be processed at any moment and thus they cannot operate in parallel nor can they interact (Pashler, 1984, 1994). According to this view, when stimuli for two tasks are presented in close succession (i.e., with a short stimulus onset asynchrony; SOA), Task 2 response selection can only begin when Task 1 response selection is completed. This causes a delay of Task 2 processing known as the psychological refractory period (PRP) effect (Telford, 1931; for overviews see Lien & Proctor, 2002; Meyer & Kieras, 1997; Pashler, 1994; Pashler & Johnston, 1998). Critically, this view implies that Task 1 processing should be unaffected by Task 2 response selection related processing.

However, a number of studies have questioned such strict bottleneck assumptions. Of particular importance for the present study is the BCE, an effect suggesting that features of stimuli and responses in both tasks can interact. For example, in a study by Hommel (1998), participants were instructed to manually press a left or right key (R1) in response to the color of a letter, and to vocally respond with "left" or "right" to the letter identity (R2). When manual and vocal responses were compatible in a trial ([right key-press, "right" vocal response] or [left key-press, "left" vocal response]), responses even in Task 1 were faster in comparison to incompatible trials (e.g., [left key-press, "right" vocal response]). This implies that features of the Task 2 response are

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certainly activated to some degree while the first response is being selected, and accordingly, the BCE challenges the assumption of a strict response selection bottleneck (see also Ellenbogen & Meiran, 2008, 2011; Giammarco, Thomson, & Watter, 2016; Hommel & Eglau, 2002; Janczyk, 2016; Janczyk, Pfister, Hommel, & Kunde, 2014; Lien & Proctor, 2002; Watter & Logan, 2006, for comparable results). These reports of BCEs do rely on (spatial) compatibility relations between stimuli and responses of the two component tasks, and our study focuses on this particular type of a BCE. We will come back to other types in the General discussion section, however.

To account for BCEs, several authors (Hommel, 1998; Hommel & Eglau, 2002; Lien & Proctor, 2002) suggested an automatic stimulus-response (S-R) translation process. In particular, they distinguished a stage of *response activation* from the subsequent bottleneck stage of *response selection*. Critically, the former is assumed to potentially run in parallel to all other stages of concurrently ongoing tasks, and therefore is where crosstalk between tasks arises from. Thus, the appearance of the Task 2 stimulus automatically projects activation onto the corresponding response codes through (acquired or instructed) S-R links and thereby affects Task 1 processing. In other words, some of the processes mapping the Task 2 stimulus to its appropriate response are activated automatically while the same processes are still active for Task 1.[1]

1.2. Free- and forced-choice tasks

One way to investigate the importance of such automatic S-R translation is to compare the size of the BCE between tasks where the strength of the S-R links differs, but which are comparable in other aspects such as the number and type of responses. We here opted for comparing the BCEs for forced- vs. free-choice tasks (Berlyne, 1957; for recent overviews, see also Janczyk, Nolden, & Jolicoeur, 2015; Janczyk, Dambacher, Bieleke, & Gollwitzer, 2015). In a *forced-choice task*, a particular stimulus unambiguously indicates one specific and correct response. In contrast, in a *free-choice task*, participants are to choose from a set of response alternatives upon a specific stimulus. Often, and also in the present study, forced- and free-choice tasks are intermixed within blocks. Instructions for the forced-choice task may then be "If an X is presented, press the left key; if an S is presented, press the right key", and for the free-choice task they may be "If an H is presented, please choose spontaneously to press the left or the right key". One typical observation are longer response times (RTs) in free-choice than in forced-choice tasks. Even though this difference has implicitly been attributed to different modes of response selection (e.g., Herwig, Prinz, & Waszak, 2007), recent work has attributed this difference to a facilitation of perceptual processing in the case of forced-choice stimuli (Janczyk, Dambacher et al., 2015). Further supporting the idea that both tasks do not differ with regard to response selection, they appear equally susceptible to dual-task interference (Janczyk, Nolden et al., 2015).

Thus, free- and forced-choice tasks share many commonalities and they use the same responses when presented randomly intermixed, but they differ in one important aspect: In forced-choice tasks, particular S-R links are instructed (and can thus act in the form of a "prepared reflex"; see Hommel, 2000), and are further established/strengthened in the course of an experiment because each forced-choice stimulus S_{forced} is (correctly) responded to with one particular response R. In free-choice tasks, in contrast, no particular S-R instruction is provided, but rather it is often mentioned that both responses should be chosen about equally often in the course of the experiment. While no S-R link is thusly instructed in free-choice tasks, repeated presentation of a stimulus and execution of responses to it can lead to a build-up of S-R links (see Damian, 2001). Further, there is evidence that such S-R links can develop rather quickly (Wolfensteller & Ruge, 2011). In sum, there is reason to assume that the free-choice stimulus S_{free} can also build links with both responses R, even though these links will be weaker compared to those with S_{forced}. Moreover, encountering the S_{free} means that both responses are activated to some degree, while encountering an S_{forced} automatically activates only its one associated response, and this more strongly.

1.3. The present research

We report the results from three dual-task experiments that were modelled after the design used, for example, by Hommel (1998) and Janczyk (2016). On each trial of the experiments, participants performed two tasks and the main interest was on Task 1 performance. In Experiments 1 and 2, Task 2 was always a forced-choice task, but Task 1 was either a free-choice or a forced-choice task. In Experiment 3, this order was reversed and Task 1 was always forced-choice, but Task 2 was either free- or forced-choice.

Assuming that the appearance of the Task 2 stimulus activates response features that facilitate and/or interfere with concurrently activated response features in Task 1, a first straightforward prediction is that in all conditions where Task 1 and 2 are forced-choice, a standard BCE should be observed in RT1s. Note that this just described situation is the one realized in most other studies on the BCE. More interesting are the results obtained for the free-choice Task 1 trials. If a free-choice task occurs as Task 1 – as in Experiments 1 and 2 – the strong activation of one particular response resulting from Task 2 processing should also induce a BCE as measured in RT1s, albeit of smaller size than for the forced-choice Task 1 trials. Additionally, these experiments allow us to investigate whether the Task 2 response activation not only speeds Task 1 response emission up, but also affects *which* response is actually emitted in a free-choice task. If this were the case, a bias towards the response location required in Task 2 is expected. For Experiment 3, both particular responses are activated in free-choice Task 2 trials, and thus no particular response location will be equipped with an advantage over the other, and no BCE is expected in this case. There is some evidence that following the emission of the first response, Task 2 response selection does not take into account earlier activation (Janczyk, 2016; Logan & Delheimer, 2001). Thus, it is not straightforward to predict a bias in Task 2 free-choice towards the location of the Task 1 response.

2. Experiment 1

Experiment 1 employed a standard BCE paradigm with the simultaneous onset of two stimuli (the color and the identity of a letter). Task 1 responses were discrete manual left/right key-presses and Task 2 responses were left/right foot pedal-presses, respectively. We used this combination of response modalities because they yielded large BCEs in pilot studies and have also been used in other recent studies from our lab (e.g., Janczyk, 2016; Janczyk, Büschelberger, & Herbort, 2017). While Task 2 was always forced-choice, Task 1 was either forced- or free-choice randomly intermingled.

2.1. Methods

2.1.1. Participants

Thirty-six people from the Würzburg area participated (Mean age = 23.1 years, 30 female) for monetary compensation. All participants reported normal or corrected-to-normal vision, were naïve regarding the underlying hypotheses, and provided written informed consent prior to data collection.

[1] There is some evidence that the stimulus S does not directly activate a corresponding efferent motor signal, classically understood as the response R, but rather features of sensory effects E resulting from the motor movement (Janczyk et al., 2014). For the present purposes, it does, however, not matter whether the link is S-R or S-E, and we will only refer to S-R links here.