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Backward crosstalk and the role of dimensional overlap within and between tasks[☆]

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ABSTRACT

In dual-task situations, which often involve some form of sequential task processing, features of Task 2 were shown to affect Task 1 performance, a phenomenon termed "backward crosstalk effect" (BCE). Most previous reports of BCEs are based on manipulations of code compatibility between tasks, while there is no clear picture whether and how mere Task 2 response selection difficulty (in the absence of cross-task dimensional code overlap, including effector system overlap) may also affect Task 1 performance. In the present study, we systematically manipulated response-response (R1-R2) relation (compatible, incompatible, arbitrary) and the stimulus-response (S-R) relation in Task 2 (S2-R2: compatible, incompatible, arbitrary; i.e., a classic manipulation of Task 2 response selection difficulty) to study the impact of dimensional overlap and compatibility within and across tasks using an integrated stimulus for both a vocal Task 1 and a manual Task 2. Results revealed a replication of a classic (spatial) R1-R2 compatibility BCE (based on code compatibility), demonstrating that our paradigm is principally suited to capture typical BCEs. Importantly, conditions involving a removal of dimensional code overlap between tasks still yielded an effect of mere Task 2 response selection difficulty on Task 1 performance. Both types of BCEs (i.e., BCEs based on code compatibility and BCEs based on Task 2 difficulty) could be assumed to be rooted in anticipation of response selection difficulty triggered by stimuli indicating either R1-R2 or S2-R2 incompatibility. The results are in line with recent theoretical claims that *anticipations* of response characteristics (or effects) play an important role for BCEs in particular and for conflict resolution in action control in general.

1. Introduction

Crosstalk is known as one of the major sources of interference in dual-task control (e.g., Logan & Gordon, 2001; Pashler, 1994). In a pioneering study by Navon and Miller (1987), who introduced the metaphor of crosstalk into research on elementary cognitive mechanisms, crosstalk referred to *content-based* cross-task conflict (e.g., conflict between one task requiring a "left" response and another, concurrent task requiring an incompatible "right" response). The notion of crosstalk implies that the simultaneous and parallel processing of two tasks is never fully encapsulated for each component task. Crosstalk effects can be further subdivided into forward and backward crosstalk, depending on whether features of the first task (Task 1, usually the task in which participants respond first) affect Task 2 processing or vice versa. While forward crosstalk is notoriously difficult to distinguish from other sources of interference (e.g., content-independent processing bottlenecks), previous research has demonstrated many convincing instances of backward crosstalk effects (BCE; see Lien & Proctor, 2002; Fischer & Plessow, 2015, for reviews).

1.1. Backward crosstalk

Hommel (1998) has demonstrated a BCE emerging from both stimulus- and response-related feature overlap across tasks. For example, he had participants respond to colored (red or green) letters ("S" or "H"). Color was mapped to a left/right manual key press (Task 1), letter identity to a "links"/"rechts" (German for "left"/"right") vocal response (Task 2). As a result, a significant *spatial R1-R2 compatibility BCE* emerged in Task 1 response times (RTs), with shorter RTs when both tasks required the same (vs. different) spatial response code(s). In other experiments, Hommel (1998) slightly changed the setup by mapping letter identity in Task 2 to uttering the color words "rot"/"grün" (German for "red"/"green"), thus introducing a manipulation of S1-R2 compatibility. As a result, Task 1 RTs were prolonged for incompatible

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(vs. compatible) S1-R2 relations. These *BCEs* based on code overlap between tasks (either between spatial response codes across tasks or between semantic stimulus codes in Task 1 and semantic response codes in Task 2) were particularly interesting because it has previously been assumed that response-related features in Task 2 are only processed *after* response selection in Task 1 has been finished (serial response selection bottleneck: Pashler, 1994), an assumption that precludes an influence of response-related Task 2 features on Task 1 performance and that is therefore not reconcilable with these BCE phenomena. Further research has consistently replicated such BCE with different kinds of feature overlap across tasks or responses (e.g., Ellenbogen & Meiran, 2008; Hommel & Eglau, 2002; Huestegge & Koch, 2009; Lien & Proctor, 2000; Logan & Gordon, 2001; Thomson, Danis, & Watter, 2015; Watter & Logan, 2006), and even for 5- to 6-year-old children (Janczyk, Büschelberger, & Herbort, 2017) and older adults (Janczyk, Mittelstaedt, & Wienrich, 2018). The traditional explanation for this type of BCE is based on the assumption of parallel activation of response-related codes across tasks prior to response selection in the first task (i.e., in a parallel processing stage usually termed “response activation”), which either yields Task 1 processing delays due to interference between spatially incompatible codes (response code competition), or (relative) Task 1 acceleration in the case of compatible response codes due to cross-task response priming (Hommel, 1998; Lien & Proctor, 2002). Alternatively, automatic Task 2 response activation may also directly affect Task 1 response selection, similar to the flankers in a flanker task (Janczyk, Renas, & Durst, 2018; Thomson et al., 2015).

1.2. Types of backward crosstalk

However, a closer look at the literature suggests that several different types of BCEs may need to be distinguished. While in the study by Hommel (1998) crosstalk referred to cross-task conflict between two *task-relevant* codes (i.e., codes that are necessary parts of the component tasks' instructions such as spatial response features or color), subsequent research demonstrated other instances of BCE. For example, Miller and Alderton (2006) showed that instructed Task 2 response force (soft/strong in response to letter identity) affected response force in a Task 1 that only involved left/right key presses to stimulus color (i.e., without any instructions regarding response force in Task 1). This finding indicates that BCE can also affect *task-irrelevant* (non-instructed) response features, that is, features relevant only for instructions of the other, secondary task. Nevertheless, this BCE can still be conceptualized as being based on cross-task code overlap, because responses in both tasks must be executed with a particular response force even when Task 1 instructions do not explicitly refer to this.

A final interesting type of BCE has been termed “no-go BCE”. Miller (2006) reported evidence that withholding responses in Task 2 in some (“no-go”) trials prolonged Task 1 processing (see also Janczyk & Huestegge, 2017; Röttger & Haider, 2017). This is an interesting finding because at first sight it is not clear why any backward crosstalk could occur under such conditions: The absence of R2 should leave no room for any R2-related feature to affect Task 1 performance. One way to explain this effect is to assume that no-go trials differ from go-trials with respect to the presence of a (rather global) inhibitory process that impacts on Task 1 response processing or execution (Durst & Janczyk, 2018; Miller, 2006; see also Aron, 2011, for similar global inhibitory effects involved in stopping responses). Another possibility is that the specific *stimulus* indicating no-go trials automatically activates a “no-go” response code, which interferes with the selection of the (conceptually incompatible “go”) response in Task 1. Some empirical evidence for the latter claim was provided by Röttger and Haider (2017), who demonstrated a lack of a no-go BCE in situations where no-go trials were not associated with a specific stimulus. Irrespective of the specific mechanisms, the “no go” BCEs can only be explained by referring to cross-task conflict on a more abstract level (i.e., conflict between execution and inhibition), and not by assuming cross-task conflict between more specific task-relevant (instructed) stimulus- or response-related processing codes (such as “left” and “right”).

Janczyk and Huestegge (2017) followed up on the “no-go” BCE by determining the conditions under which Task 2 “no-go” demands yield performance costs or benefits in Task 1. Across a set of experiments, they manipulated whether Task 2 was a choice “go/no-go” task or a simple “go/no-go” task (the latter “go” response presumably being easier to prepare). The results suggested that a “no-go” BCE specifically occurs when Task 2 “go” responses are comparatively likely to be prepared (e.g., when the corresponding response is easy to select/configure, as in a simple RT task), subsequently requiring more inhibitory demands that negatively impact on Task 1 when compared to a less likely prepared (more difficult to select/configure) Task 2 response (as in a choice RT task). The latter case, given that there is no need for strong inhibition since there is not much to be inhibited, even yielded beneficial effects on Task 1 performance in “no go” Task 2 conditions. This observation is already first evidence that Task 2 response selection difficulty may affect Task 1 performance. However, this conclusion is rather indirect in that it refers to inhibitory processes and thus requires several (albeit plausible) assumptions, and a more direct test of the extent to which mere Task 2 response selection difficulty may affect Task 1 performance is clearly necessary.

1.3. Anticipatory processes in dual-task control

Recently, it has been proposed that *anticipation processes* may also play a major role, at least for the R1-R2 compatibility BCE. More specifically, Janczyk, Pfister, Hommel, and Kunde (2014; see also Renas, Durst, & Janczyk, 2017) studied which specific features of the second response are represented prior to or during R1 selection. They demonstrated that anticipated (visual) effects produced by R2 had a strong effect on R1 processing. These findings suggest that anticipated features of R2 (including its effects) can affect Task 1 processing relatively early in the processing chain. The impact of anticipation on dual-task control processes was further demonstrated by studies showing that mere expectation of an occasional additional task can slow down a prioritized Task 1 (e.g., Miller & Durst, 2014). Based on these considerations, it appears possible that mere anticipation of Task 2 response selection difficulty can also affect RT1 even in the absence of dimensional overlap across tasks. However, up to now there is no study which systematically addressed both the role of (spatial) R1-R2 compatibility and Task 2 (S2-R2) relation (as a typical manipulation of Task 2 response selection difficulty) on BCEs within a single, comprehensive experimental design.

1.4. Task 2 (response selection) difficulty effects

There are several previous studies involving manipulations of Task 2 (response selection) difficulty in a dual-task design. For example, a study by McCann and Johnston (1992) utilized a PRP design in which Task 1 involved vocal “high”/”low” responses to high/low tones, while response selection difficulty was manipulated in Task 2. In Experiment 1, Task 2 involved manual responses with three fingers to triangles/circles of three different sizes. As a classic manipulation of response selection difficulty, S-R mappings in Task 2 were either easy (smallest size – leftmost finger, medium size – middle finger, largest size – rightmost finger) or difficult (arbitrary mapping of stimulus size to fingers). While the authors were mainly interested in RT2 effects, they also reported a very small (5 ms) but significant effect of Task 2 response selection difficulty on RT1. However, different types of Task 2 response selection difficulty manipulations in Experiment 2 of this study did not yield significant effects on Task 1 performance. Probably, the ease of S-R translation in Task 1 (high/low tone – say “high”/”low”) may have prevented consistent effects on Task 1 performance. Another drawback of this study (at least for our present purpose) is that there