Contextualization in perception and action

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ABSTRACT

It is proposed that cognitive representations of perceived and produced events (i.e., perception and action codes) are contextualized by integrating them with codes of events they accompany. Supporting empirical evidence coming from several lines of research is reviewed. Indeed, there is converging evidence that stimuli become integrated with the response and the task they signal or accompany, so that re-viewing a stimulus tends to re-activate the previously related response and task. However, even though the integration of context events seems to occur automatically, it is affected by attentional control settings. A dimensional-priming model is suggested that can account for this interaction of automatic and attentional processes.

Human action is flexible and adaptive in several respects. Obviously, and fortunately, we are not bound to respond to perceived events in a particular, reflex-like manner but we can often choose among several, more and less optimal responses, modify our reactions to make them more efficient, and even develop novel methods to deal with particular stimulus demands. An important aspect of this adaptivity is our ability to consider the situational context in which a particular event is acted upon, and a particular action is carried out (Hoffmann, 1993). Indeed, many behaviors would either fail to reach their ultimate goal or lead to most unwanted side-effects if the context in which they unfold would not be taken into consideration. For instance, pressing the keys on a computer keyboard will only produce text on a screen if the computer is switched on and the proper text processor has been loaded; the effect of uttering the word "bellen" will be quite different during a conversation held in Dutch (where it refers to giving a phone call) or in German (where it means to bark); and entertaining a friend by telling jokes is perfectly acceptable in a bar but not in a church. To master these situations requires more than just acquiring and applying particular stimulus-response rules or associations, the actor also needs to relate them to the appropriate context—a process that we will call *contextualization*.

The importance of contextualization is obvious even in simple laboratory tasks. Consider, for instance, the well-known Stroop task, which requires the speeded naming of the ink of color-name stimuli. Without further instruction, facing the word GREEN in red ink on a computer screen might induce many reactions: one might want to tell other people about this incident, copy the stimulus on paper, memorize it, call the computer helpdesk, and so forth; yet, the presumably most overlearned response would be to read the word (i.e., to say "green"), at least silently. If so, this would indicate some kind of association between the stimulus representation and the corresponding verbal response, i.e., between the cognitive code of the word GREEN and a motor pattern producing the utterance "green". If such an association exists in subjects performing a Stroop task, and if it is stronger than others, how can subjects nevertheless succeed in producing another, conflicting response, such as saying "red" to the word GREEN? Apparently, there are cognitive mechanisms that allow us to react to such stimuli in a context-sensitive fashion, that is, we can learn to distinguish between situations where saying "green" to an incongruent Stroop stimulus is most appropriate and other situations where only the response "red" is acceptable.

How such a mechanism may look like has been considered by Cohen and colleagues (Cohen, Braver & O'Reilly, 1998; Cohen, Dunbar & McClelland, 1990). They assume that the flow of activation from stimulus to response codes is mediated by a system that provides context information, just as sketched in Figure 1. Basically, the function of this system is weighting the different features of a stimulus with reference to the task goal, so that task-relevant stimulus features contribute more strongly to response selection than irrelevant features. In the Stroop example, perceiving the word GREEN in red ink would activate both the GREEN word code and the RED color code, which then spread activation to the corresponding vocal responses. However, as according to the instruction colors but not words are relevant, color-related activation will be boosted, so that the corresponding response will receive more activation. Therefore, it will win the competition with the much weaker word-related response (at least most of the time), so that the correct response will be given. An analogous story applies to the word-picture task we will get back to later in this article. In such a task, subjects are confronted with compounds of pictures and—commonly incongruent—words, like in the example shown in Figure 1, and they are required to name the picture. Again, both picture and word would activate their corresponding vocal responses, but mediation through the proposed context system would make sure that the picture-related response will eventually be performed.

================== FIGURE 1.===================

Context-mediated processing along the lines of Cohen's model is also likely to play a crucial role in task-switching performance, that is, in tasks requiring people to switch between two or more tasks from trial to trial. Consider the task version employed in the seminal paper of Allport, Styles and Hsieh (1994). They presented subjects with incongruent Stroop words, such as GREEN in red ink, and had them alternate between naming the ink ("red") and reading the word ("green"). Again, responding correctly required subjects to consider the context in which a stimulus was presented, hence, whether it appeared under naming or reading instruction—which in the Allport et al. study was signaled by list position. As Meiran (2000; Meiran, Chorev & Sapir, 2000) has pointed out, this might be achieved by shifting the attended stimulus dimension, which would correspond to alternating between the two nodes in Cohen et al.'s (1998) context system (see Figure 1, left panel).

In this article we will provide an overview of recent studies from our lab that provide further evidence for context-mediated processing. We will focus not so much onto the contextualization process itself but on its outcome, hence, on how it affects the further processing of stimuli, responses, and stimulus-response relations. In particular, we will show evidence suggesting that stimuli, responses, and stimulus-response episodes are bound to, and integrated with, the situational context and the task in which they are processed. This integration makes it easier to process them again in the same context, but more difficult to deal with them in a different context.

CONTEXTUALIZATION OF STIMULUS EVENTS

The contextualization idea implies that the cognitive representations of stimulus events are toned by, and integrated with other events they accompany. This may be other stimuli in the same sensory modality—like in processing a letter in a particular word—or other aspects of the same event experienced via other modalities—like in intersensory integration. It may also be a stimulus-related response the cognitive representation of which is merged with the stimulus code (cf., Hommel, Müsseler, Aschersleben & Prinz, in press). Once the integration took place re-encountering one element of the resulting cognitive chunk should tend to re-activate the associated elements, thereby facilitating the processing of the same event combinations, but interfering with processing novel or other combinations of the same elements.

Ideas of this sort have been considered in different contexts, such as feature integration in action planning (Hommel, 1998; Stoet & Hommel, 1999), automatization (Logan, 1988; Logan & Etherton, 1994) and proceduralization in memory (e.g., Crowder, 1993). For example, the instance theory of automatization (Logan, 1988; Logan & Etherton, 1994) claims that a trace of stimulus-response (S-R) processing episodes are stored in so-called "instances", in our view a possible residue of a contextualization process. According to Logan and colleagues, later responses to the same stimuli can be facilitated by the automatic retrieval of related instances, provided that the required response is the same too. To the degree that the relationship between stimuli and responses remains consistent, the repeated experience of the same processing episodes results in the accumulation of instances concerning the particular S-R combination. As Logan (1988) was able to demonstrate, this assumption corresponds nicely with the typical reaction-time speed-up observed in the early practice of tasks.

However, as we have argued, stimuli do not invariably call for the same actions. In fact, most events we encounter provide rather few constraints on our actions—just think of the huge amount of social interactions making up our daily life. Thus, as important as the development of stable routines warranting the fast and accurate handling of recurrent situations may be, most stimulus events afford quite different actions in different contexts. This calls for some contextualization mechanism ensuring that stimulus-oriented action is context-sensitive (cf., Monsell, 1996).

As already mentioned, one way to study context-sensitive processing is to investigate task-switching behavior. In a typical task-switching experiment, subjects alternate between two different tasks, the standard measure being choice reaction time (e.g., Allport et al., 1994; Meiran, 1996; Rogers & Monsell, 1995). The subjects' “switching“ performance is compared with non-alternating control performance on the same task. A variety of studies have shown that shifting between tasks incurs a considerable temporal cost (e.g., Jersild, 1927; Rogers & Monsell, 1995; Spector & Biederman, 1976), i.e., reaction times are larger immediately after a task shift as compared to repeating the same task across consecutive trials. Furthermore, it has been shown that under most conditions the observed switching costs can be reduced but not eliminated by signalling the upcoming task in advance and providing a long time for preparation. This irreducible component is commonly referred to as “residual“ switching costs, and has been reported by several authors (e.g., Allport et al., 1994; De Jong, Emans, Eenshuistra & Wagenmakers, 2001; Fagot, 1994; Rogers & Monsell, 1995; Meiran, 1996). The most common explanation of RT cost in task switching experiments is that switching between tasks relies on some executive "shifting process" which disengages the irrelevant task set and engages the subsequently relevant task set (e.g., Rogers & Monsell, 1995). To account for residual switch costs, Rogers and Monsell proposed an "exogenous" switching process, which can not take effect until it has been triggered by an appropriate task stimulus.

Recently, however, we found evidence suggesting that this conceptualization may be overgeneralized. Indeed, at least residual switching costs are no pure measures of the time needed to engage and disengage appropriate task-sets, at least not in terms of an executive control process. Instead, we suggest that a large part of the task shift costs is due to the retrieval of incompatible stimulus-response episodes, created in prior trials in which the same stimuli occurred in the competing task context. Here we follow the line of thought underlying the “task-set inertia“ (TSI) account put forward by Allport and colleagues (1994). They proposed that the residual cost of task switching results from the involuntary persistence of the preceding task-set, which causes a time-demanding interference due to a conflict between the competing tasks. More recently, Allport and Wylie (1999, 2000) reformulated the task-set inertia account. They proposed that, rather than necessarily persisting across trials, the previously appropriate task-demands might also be retrieved from memory, when stimuli recently associated with these demands are presented again (cf., Hommel, 1998).

In a series of experiments we explored these converging ideas in more detail (Waszak, Hommel & Allport, 1999, 2000, 2001). In most task switching experiments conducted so far, the stimulus sets for the two tasks overlap completely, i.e. the same small set of stimuli was used for both tasks. Consequently, these experiments do not allow separating effects that arise because subjects have to switch between different processing pathways from effects which arise because subjects are required to respond to the same experimental stimuli in two different, competing task contexts. We avoided this problem by using picture-word (Stroop) stimuli. This provided us with a large number of possible words and pictures, making it possible to create a very large item-pool, and, thus, to deconfound tasks and stimuli easily.

In all our experiments, subjects named pictures and read words, switching task every third (in some experiments every second) trial. All picture-word stimuli presented were incongruent, that is, pictures and words signalled different, competing responses. The main purpose of our experiments was to deconfound tasks and stimulus set by probing subjects' performance on stimuli that were presented either in both competing task contexts—picture-naming and word-reading, as in most previous experiments—or in only one of the competing task contexts. The central idea was that any effect attributable to the retrieval of conflicting S-R episodes—which should emerge when the same stimuli appear in different, competing task contexts—should be restricted to the item set presented in both tasks contexts. However, if the costs of task switching were due to some executive reconfiguration process setting up the correct processing pathways (e.g., Rogers & Monsell, 1995), all stimuli should be affected, regardless of whether they had been presented in the competing task context or not.

In one of our experiments (Waszak, Hommel & Allport, 2001, Experiment 1) we used a set of 108 picture-word Stroop stimuli. The manipulation of stimulus overlap was as follows. The 108 stimuli were divided into three stimulus subsets: PW (Picture-naming and Word-reading), PO (Picture naming only), and WO (Word-reading only). For the picture-naming task, subjects were presented with stimulus items of set PO and set PW; for the word-reading task, subjects were presented with stimulus items of set WO and set PW. Thus, subjects performed word-reading switch and repeat trials which were triggered either by stimulus item which previously occurred in the competing picture naming task (PW), or by stimulus items which in the whole experiment were not presented for picture-naming (WO).

The results were clear-cut (see Figure 2A): Stimuli which occurred under word-reading only, showed a switch cost of about 100 ms (set WO); stimuli presented in both tasks, by contrast, showed a switch cost of about 230 ms (set PW). Thus, the experiment revealed a large item-specific component of the costs of task-switching. Switching task in response to stimuli presented in both task contexts more than doubled the switch cost of stimuli presented in word-reading only. This effect of word-reading stimuli being primed by prior presentation for picture-naming is relatively long-lasting, because the stimuli were presented in such a way that the mean lag between the occurrence of an item for picture-naming and the subsequent presentation of the same item for word-reading was eight trials.

================== FIGURE 2.===================

Further experiments (Waszak et al., 2001, Experiments 3 and 4) even show that the item-specific increase of the cost of task switching can at least survive 100-200 intervening trials between the two events. Moreover, further analysis revealed that a single picture-naming presentation of a given item is sufficient to result in a large increase of switch costs when the same item later-on is presented in a word-reading switch trial. We consider these results to support the suggestion from Allport and Wylie (2000), that stimuli acquire associations (bindings) with the tasks in which they occur, and that a subsequent presentation of that stimulus can automatically retrieve the associated task. On a switch of tasks, when the current task activation is rather weak, this retrieval of the competing task interferes with execution of the intended task.

Retrieval-based models assume that integration of cognitive codes proceeds by accumulating episodic traces or instances (e.g., Logan, 1988; Logan & Etherton, 1994), or by strengthening connections between the integrated elements (e.g., Cohen et al., 1990). Therefore, such accounts predict that processes based on these instances or connections are the more efficient the more instances accumulated in memory or the “stronger“ the connections. Following this logic, we investigated whether presenting an item several times in picture-naming (before the occurrence of the same item in word-reading) yields a larger cost of task switching then presenting the item once in picture-naming and later-on once in word-reading (Waszak et al., 2001, Experiment 2).

This experiment was very similar to the one described above. The main difference was that there were two subsets of items presented in both task contexts, word-reading and picture-naming. Before they were presented once for word-reading, the items of one subset (PW1) were each presented once for picture-naming, while the items of the other subset (PW4) were each presented four times. As in the previous experiment, one item set was not presented at all for picture-naming (WO). Again, switch cost for items of set WO were the smallest, as shown in Figure 2B. More important, task switch cost was, as predicted, significantly larger for items of set PW4 than for items of set PW1. This clearly supports the assumption that the cognitive system stores some memory trace of processing an item in a particular task context (picture-naming in this case), and that this record can be retrieved when the item is presented again. The more (or stronger) traces involving one task (picture-naming) accumulate in memory, the more impaired the performance when the stimuli are presented during the other task (word-reading).

CONTEXTUALIZATION OF ACTIONS

As already mentioned, in the case of language context-dependencies of actions are a very common phenomenon: the function and meaning of a phonem in a word, of a word in a sentence, and of a sentence in a speech all depend heavily on the situation in which a verbal action is performed. But many manual actions depend on context as well: Just think of moving a lever, which may open a door, increase speed of a plain, or launch a rocket. Indeed, changing the context can turn an entirely appropriate action into a worst case scenario, which suggests that the cognitive representations of actions are linked to information about contexts into which that action may possibly fit. Actually, this argument is little more than the other side of the coin of the arguments for contextualizing stimulus representations.

As we will see, there is in fact evidence that actions get bound to context cues their occurrence is correlated with. To anticipate, this integration seems to proceed automatically, though attentional processes play a mediating role. And this is what one would expect: As one typically does not know about possible future contexts and available context cues, it would make sense that integrating an action with its context is automatic to at least some degree.

To study context integration, Hommel (1998) deviced a dual-trial design that required performing a precued, simple left or right keypress (R1) to the *onset* of a stimulus (S1), followed by a binary-choice (left-right) response (R2) to a particular feature of a second stimulus (S2). The stimuli varied in their shape (O vs. X), color (red vs. green), and location (top vs. bottom). As R1 was signaled by a cue more than a second before S1 appeared, the features of S1 were completely irrelevant to the task in general and R1 in particular. Hence, the identity of S1 provided only a visual context in which R1 was performed. If information about context would be integrated, the features of S1 and R2 should get bound. If so, this should affect performance on R2 depending on whether the features of S1 and S2 and those of R1 and R2 overlap or not.

================== FIGURE 3.===================

Figure 3 provides an overview of Hommel's (1998) main findings. The left panels show performance on R2 in Experiment 1A, where subjects responded to the shape of S2. It can be seen that performance was good if the shape of S2 and S1 matched *and* R2 was a repetition of R1. Given that R1 and R2 were performed in a sequence, with an inter-stimulus interval of only 1 second, this is hardly surprising and might merely reflect the combination of two independent repetition effects. However, performance was as good if there was a mismatch of *both* the shape of S2 and S1, *and* the identity of R2 and R1—a condition for which a repetition-benefit account would predict the worst results! In other words, performance was best if either both or none of the elements of the shape-response conjunction was repeated, but it was impaired if the repetition of one element was mixed with the alternation of the other: a true conjunction benefit. This observation suggests that performing R1 in the context of S1 leads to the integration of S1 and R1 features, so that encountering one of these features again leads to the re-activation of the other. This is likely to hamper performance in the case of partial feature repetitions—i.e., new feature combinations—because then one of the two activated features is misleading.

It is interesting to note that stimulus location interacts with response repetition in very much the same way as stimulus shape, whereas stimulus color does not (see middle of left panels). Part of the reason for this pattern is revealed in the right column of panels, which refers to Hommel's (1998) Experiment 2, in which subjects reacted to the color of S2. Here, shape did not interact (strongly) with response while color did. Apparently, task relevance of a stimulus feature modulates the way stimulus features and responses are integrated, so that only task-relevant, attended features become bound to responses. That is, the contextualization of response representations proceeds automatically, but which cues are integrated is determined—or at least affected—by which feature dimensions are attended. Obviously, this is exactly what Cohen et al.'s (1998) context model and Meiran et al.'s (2000) model of task-switch control would lead one to expect. It is interesting to note that even the observation of interactions between stimulus location and response repetition in both Hommel's (1998) Experiment 1A and 2 seems to fit into this picture. In an unpublished study we replicated the basic experiment, however, this time with non-spatial responses (tapping once or twice with a finger). As it turned out, this modification eliminated the location-response interaction. This suggests that stimulus location is integrated with responses only if response location matters, so that location as such becomes task-relevant. Accordingly, location is attended and its processing facilitated, much like shape in Hommel's (1998) Experiment 1A and color in Experiment 2.

Even though context integration is affected by the *content* of attention, hence on which dimensions attention is focused, integration does not seem to depend on attentional resources. Among other things, this is demonstrated in experiments that attempted to make the critical S1 even more irrelevant than in Hommel's (1998) original study. For instance, evidence of response-context (R1-S1) binding has been found in go as well no-go trials of a go/no-go task, if R1 was signaled by a tone that the visual S1 only accompanied, and independent of how difficult this tone was to discriminate (Hommel, 2001). Thus, no attempt to either distract attention or to exhaust attentional resources was successful in eliminating context integration, which suggests that this is a truly automatic process.

CONTEXTUALIZATION OF STIMULUS-RESPONSE EPISODES

The evidence reviewed so far suggests that stimulus representations are integrated with the response they accompany and/or the task they appear in, and that response representations are integrated with stimuli appearing about the time the response is made. The next question we asked was whether stimulus-response bindings themselves get contextualized, that is, whether S-R events are integrated independent of the task context they occur in, or whether information about this context becomes an integral part of the resulting cognitive event structure.

One way to answer this question is to investigate whether the conjunction benefits observed by Hommel (1998)—hence, the benefit of complete repetitions or alternations of a stimulus and a response as compared to partial repetitions—survive a task switch. Interestingly, the available models of task-switching performance allow quite different predictions as to this point.

Assume, for instance, executive control functions establish an entirely different task set for each given task, as the approaches of Norman and Shallice (1986) or Rogers and Monsell (1995) would suggest. If so, bindings of stimulus and response attributes acquired under one task should not affect performance on these attributes in another task context. In other words, the conjunction benefits should disappear with a task switch.

A second possibility is that stimulus-response integration is completely unaffected by task switches. Indeed, some authors have claimed that task-control functions are qualitatively different from other, low-level processes (e.g., Gopher, 1996; Mayr & Keele, 2000), suggesting that S-R integration processes do not interact, or depend on processes dealing with task-switching.

A third possibility is suggested by the context model of Cohen and colleagues (1990, 1998) discussed above. It may be that stimulus and response features are integrated irrespective of the present task, but the resulting representation may include task-related information—a true contextualization of

S-R episodes. If so, conjunction benefits may well survive a task-switch, but changing the task context may weaken their impact on performance.

In a series of experiments (Pösse & Hommel, 2001a) we had participants responding to either the shape (angular vs. round) or the color (red vs. green) of a colored X or O. In contrast to previous task-switching experiments, not only the task but also the S-R mappings varied from trial to trial. That is, before the target stimulus appeared, subjects were presented with verbal descriptions of stimulus colors ("green" and "red") or shapes ("angular" and "round"), with the location of the particular label signaling the correct response. So, for instance, the label "green" on the left and "red" on the right side indicated the mapping "press the left response key if the stimulus is green and the right key if the stimulus is red". This display did not only indicate the S-R mapping but also the task and, in our case, the relevant stimulus dimension. Thus, two color words signaled an upcoming color task while two shape words indicated a letter task.

This design allowed for an independent manipulation of task and S-R mapping, which again permitted us to deconfound the repetitions and alternations of stimulus and response features. For instance, changing the S-R mapping from one trial to the next but keeping the task the same allowed us to repeat a response even though the stimulus color changed, or to change the response even though the stimulus color was repeated. This way, we were able to manipulate stimulus and response repetitions or alternations independently from task repetition or alternation, so that we could compare conjunction benefits after a task switch and after a task repetition.

For the sake of clarity we present the results in terms of response-repetition benefits, that is, reaction times for response alternation minus response repetition, for the different conditions of stimulus repetition or alternation. Response-repetition benefits were computed for all three stimulus transitions (complete stimulus repetition—i.e., both stimulus features repeated, partial stimulus repetition—i.e., only one feature repeated, and complete stimulus alternation). Conjunction benefits of the sort observed by Hommel (1998) would be indicated in terms of positive response-repetition benefits in the case of stimulus repetitions and negative response-repetition benefits with stimulus alternations.

================== FIGURE 4.===================

Figure 4 summarizes our results. We found that conjunction benefits were not eliminated with a task switch but they were markedly reduced. On the one hand, this observation is inconsistent with the assumption that changing a task-set provides an entirely new internal context for stimulus and response coding, as suggested by reconfiguration approaches. If it would, S-R bindings should not transfer from one task to another, hence, no conjunction benefits should have occurred. On the other hand, switching from one task to another does have an effect on the impact of S-R bindings on later performance, which is inconsistent with the assumption that integration processes are entirely independent from the processes in charge for task-shifts. What our findings therefore suggest is that task-related information becomes integrated with S-R bindings, a view that is compatible with the contextualization approach pursued by Cohen et al. (1998).

Further experiments replicated and extended these findings, with two observations being of special interest for present purposes. First, we were able to exclude an alternative interpretation from a reconfiguration approach (Pösse & Hommel, 2001b). Consider the finding that shifting to a new task does not completely eliminate the effects of S-R bindings "acquired" under the previous task set. As we have argued, such a result is inconsistent with the idea that reconfiguring the cognitive system leads to a kind of reset that wipes out after-effects from a previous set. However, one might argue that our failure to find these after-effects eliminated completely is due to the insufficient task preparation of our subjects. Although we did present task precues in advance of the target stimulus, the available time might have been too short to complete preparation for the upcoming new task, perhaps because subjects were also required to prepare the appropriate S-R mapping. We tested this consideration by systematically varying the preparation interval, that is, the time between presentation of the task cue and the target stimulus. However, there was no evidence that the length of this interval had any impact on the interaction between task switching and the integration of S-R episodes. Nor was this interaction affected by whether the task variation was predictable or random. Thus, the fact that S-R bindings survive task-shifts does not seem to be an artifact of insufficient task preparation.

A further set of experiments investigated whether irrelevant stimulus features are also included in representations of S-R episodes and, if so, whether their effects are also modified by task context (Pösse & Hommel, 2001c). To test this hypothesis, we presented a tone of one of two pitches during each trial, in order to provide an extra context variable besides the task transition. From one trial to the next the pitch was either repeated or changed. With regard to the relevant, visual stimulus features we were able to replicate the task modulation of S-R integration: Complete repetitions and alternations produced better performance than partial repetitions of only the stimulus or the response, and this effect was more pronounced with task repetitions than after a task switch. With regard to the irrelevant tone, however, there was no evidence for integration with the response, nor any indication that the tone-response relation was modulated by task repetition or alternation. This also held for a control experiment that required subjects to monitor the tones actively by presenting, once in a while, a third tone signaling to the subjects to omit the following response. That is, integration of stimuli, responses, and tasks considers only information that is currently relevant for the perceiver/actor, consistent with the observations of Hommel (1998).

CONCLUSIONS

We have reviewed evidence from several lines of research suggesting that representations of stimulus and action events are contextualized by integrating them with information related to the actions and stimulus events they accompany, or the tasks in the context of which they are carried out. Taken altogether, the available findings allow for at least four conclusions.

First, contextualization seems to be a general mechanism: There is evidence for the integration of stimulus features and responses, of stimuli and tasks, and of S-R episodes and tasks; and the logic underlying the integration process and the way its products affect later use of some or all integrated elements seem to be comparable in these cases.

Second, contextualization seems to enrich the representations of stimuli, responses, or S-R episodes, thereby modulating later access to the integrated elements. Yet, we found no evidence for a complete alteration of representations that would have eliminated effects of individual elements. For instance, effects of stimulus-response combinations (suggesting S-R integration) can be observed vis-à-vis main effects of repeating the particular stimulus or response (Hommel, 1998), and some impact of repeating or alternating a S-R conjunction can be found even if the task is changed (Pösse & Hommel, 2001a). In other words, effects of bindings a particular stimulus or response may engage in add to, but do not replace, its individual effects. This means that contextualization extends the use of an event representation but does not really change it.

Third, the phenomena we investigated suggest that integration takes place automatically. This is not to say that attention and intention of the perceiver/actor plays no role (see fourth conclusion). However, integration processes do produce chunks of cognitive codes whether these are currently useful or not, and whether they are or are not required later on. This automatic character of integration is consistent with corresponding assumptions of Logan's (1988) instance theory and of Hommel's (1998) event file approach. It also fits well with the idea that integration mechanisms and their after-effects may be responsible for at least part of the costs that occur if one switches a task (Allport & Wylie, 1999, 2000).

Fourth, even though integration does not seem to depend on any intention to integrate, the selection of what information is integrated does depend on attentional control settings. As a rule, stimulus features seem to get bound to actions only (or at least mainly) if the respective feature carries some information in the particular task context (e.g., Hommel, 1998; Pösse & Hommel, 2001c). Changing this context will induce a modification of the attentional control settings, a process that takes time and effort (Meiran 2000; Meiran et al., 2000) and that is therefore likely to represent the endogenous, preparatory component proposed by reconfiguration approaches to task-switching (Meiran, 1996; Rogers & Monsell, 1995).

================== FIGURE 5.===================

These interactions between automatic and attentional processes might be accounted for along the lines of the Dimensional-Priming Model sketched in Figure 5 (cf., Hommel, in press). This model assumes that two or more given feature codes—whether they belong to a stimulus event or action plan (Hommel et al., 2001)—are automatically integrated, that is, bound in a way that later access to one element automatically spreads activation to its new associate. However, integration only occurs if the particular code(s) reach a (perhaps variable) integration threshold. The base level of codes is affected by attentional processes, so that it increases if the particular feature dimension is attended. Consequently, less activation for a feature on that dimension is needed to reach the threshold, which increases the likelihood that this feature gets integrated with super-threshold codes of other features. This way, attentional control settings indirectly control the feature-integration process, even though they are not directly involved in feature binding itself. Interestingly, this particular type of interaction between automatic processes and attention is very similar to the interaction between automatic processes and intentions in the control of stimulus-response translation (Hommel, 2000). In both cases executive control seems to be restricted to preparing the cognitive system, whereas the actual processing is left to a rather reflex-like operating cognitive machinery.

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AUTHOR NOTES

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FIGURE CAPTIONS

Figure 1. Basic architecture of the context model developed by Cohen, Braver, and O'Reilly (1998) and Cohen, Dunbar, and McClelland (1990).

Figure 2. Task switching costs, computed by subtracting reaction times on repetition trials from reaction times on switch trials. A. Task switching costs for word-reading in Experiment 1 from Waszak et al. (2001). Set WO: items presented in word-reading only, set PW: items presented in word-reading and picture-naming. B. Task switching costs for word-reading in Experiment 2 from Waszak et al. (2001). Set WO: items presented in word-reading only, set PW1: items presented once in picture-naming before being presented in word-reading, set PW4: items presented four times in picture-naming before being presented in word-reading.

Figure 3. Summary of results from Hommel's (1998) Experiments 1A and 2.Reaction times are shown as a function of repetition or alternation of stimulus shape, color, and location, and response.

Figure 4. Response-repetition benefits (response alternation minus response repetition) in Experiment 1 of Pösse and Hommel (2001a) for reaction times (panel A) and error rates (panel B), as a function of stimulus transition and task transition.

Figure 5. A Dimensional-Priming Model of context integration. Features of a context C are automatically integrated with another, stimulus or response event, or S-R episode E, if and only if the activation level of their codes reaches some integration threshold. If activation varies below threshold, no integration occurs (P-). However, if the dimension of the respective features gets (e.g., intentionally) primed, the feature codes' base level is temporarily raised (see P+). Accordingly, code activation is more likely to exceed integration threshold, so that the corresponding context will get integrated.

Figure 1

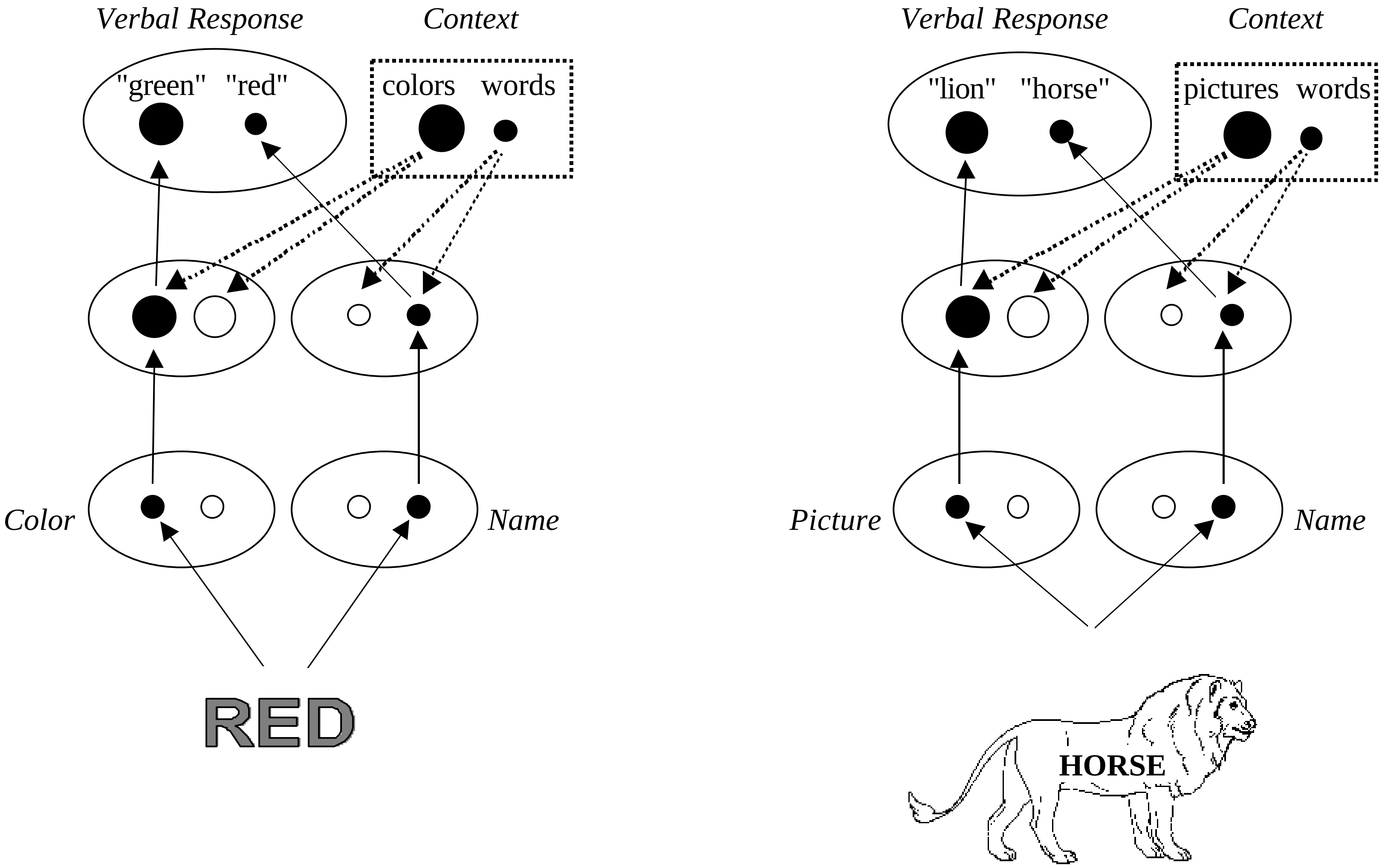

Verbal Response
Context
"green"
"red"
colors
words
Color
Name
RED
Verbal Response
Context
"lion"
"horse"
pictures
words
Picture
Name
HORSE

Figure 2

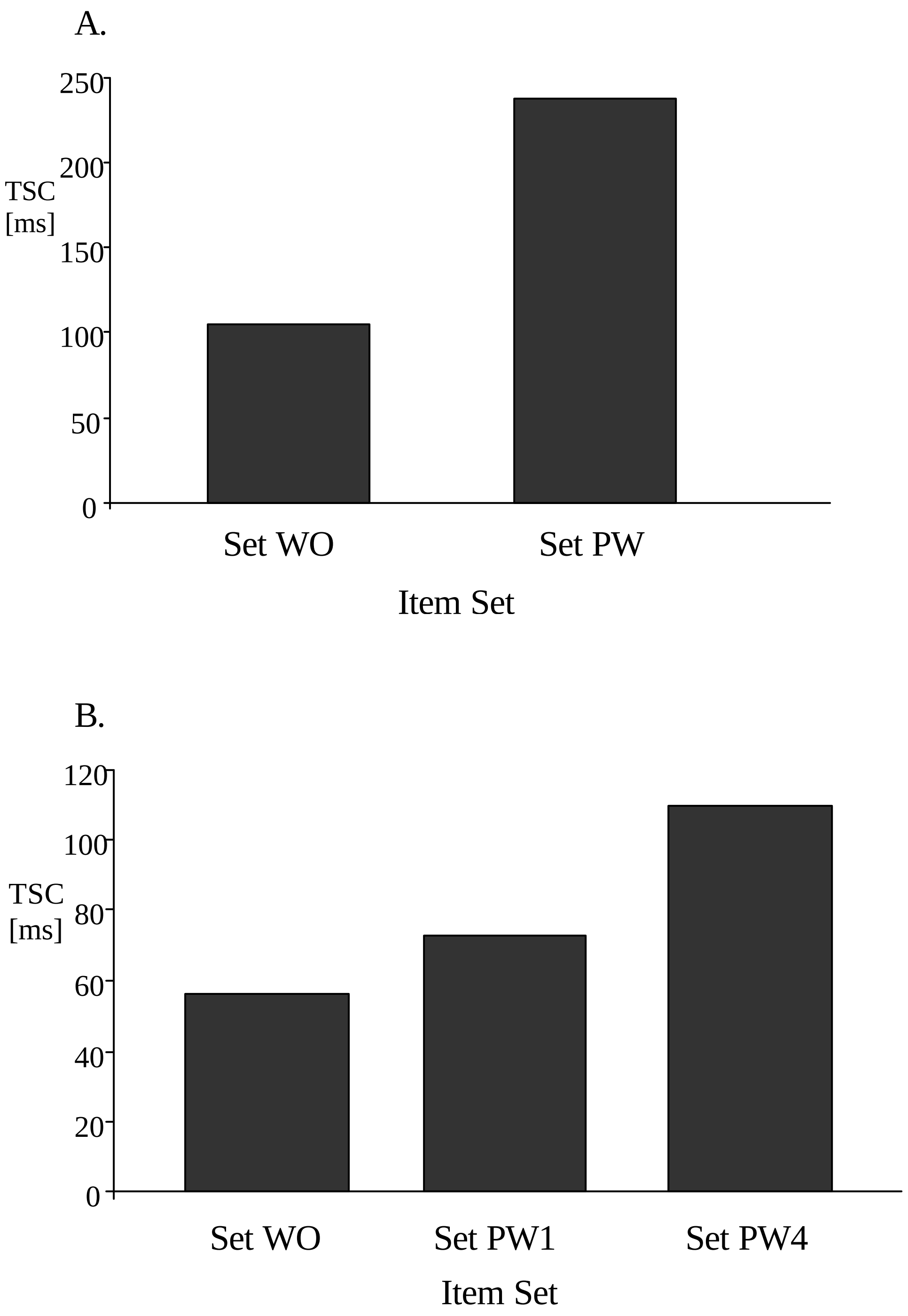

A.
TSC [ms]
250
200
150
100
50
0
Set WO
Set PW
Item Set
B.
TSC [ms]
120
100
80
60
40
20
0
Set WO
Set PW1
Set PW4
Item Set

Figure 3

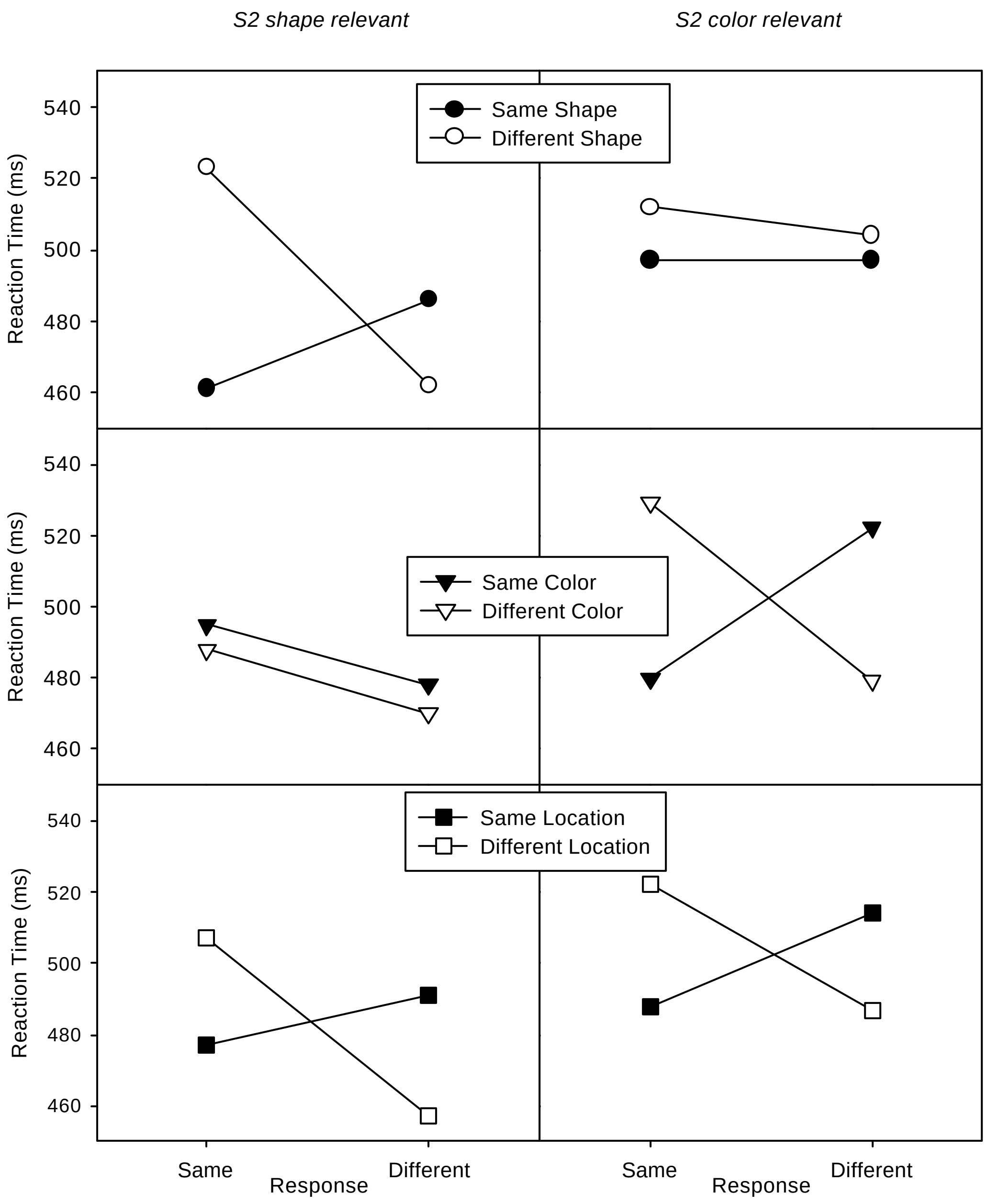

S2 shape relevant
S2 color relevant
Same Shape
Different Shape
Same Color
Different Color
Same Location
Different Location
Reaction Time (ms)
540
520
500
480
460
Same
Different
Response

Figure 4

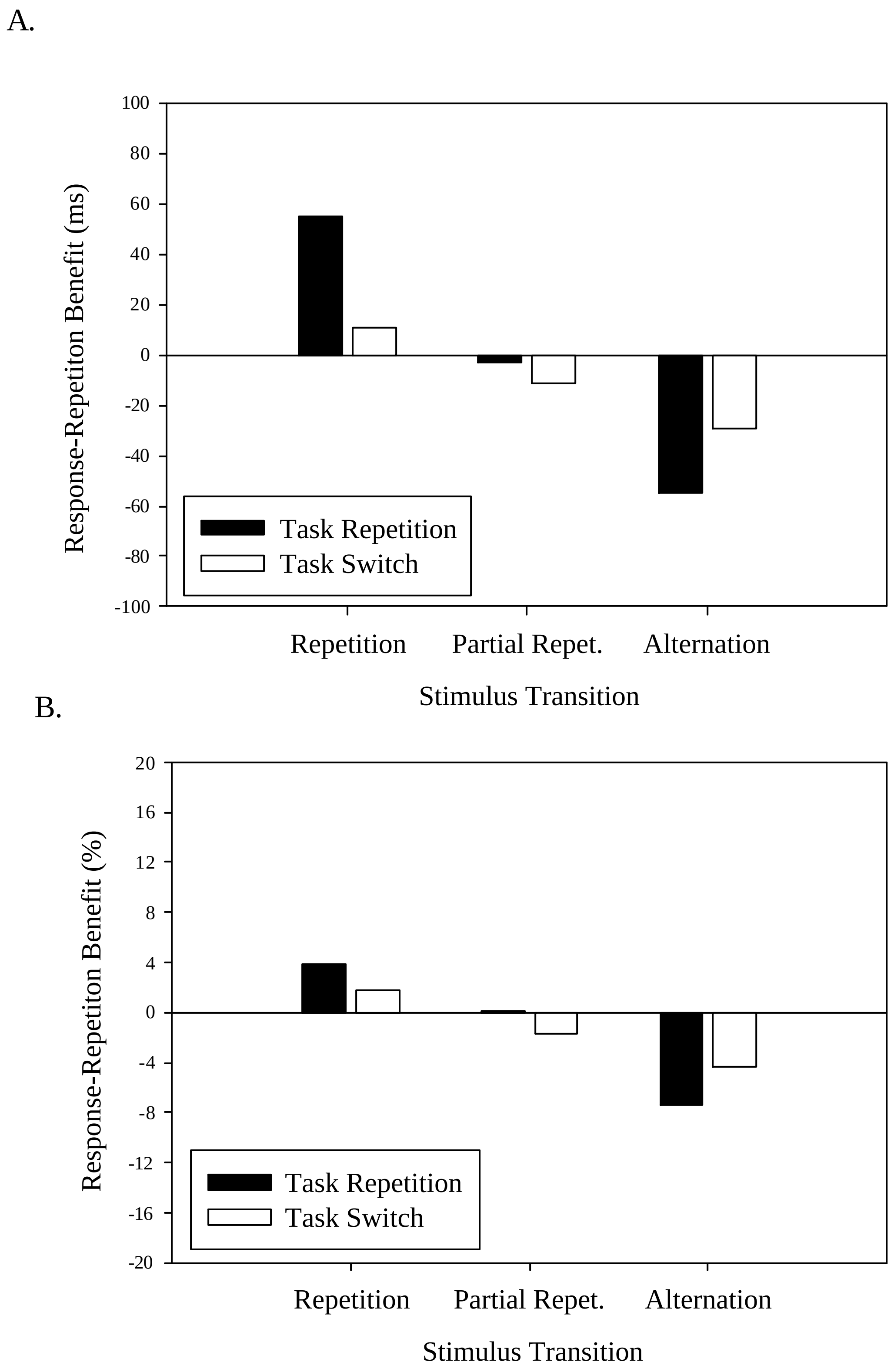
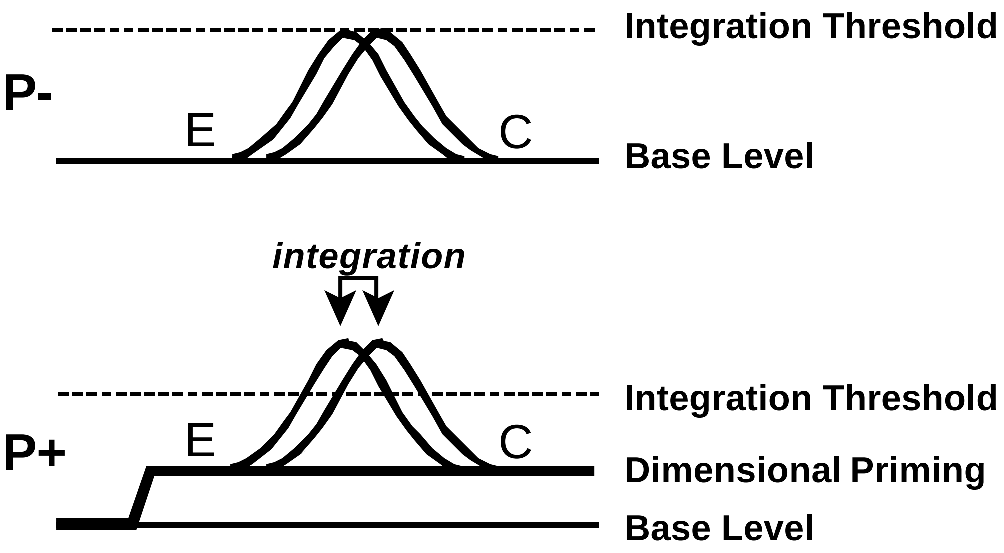

A.
Response-Repetiton Benefit (ms)
100
80
60
40
20
0
-20
-40
-60
-80
-100
Task Repetition
Task Switch
Repetition
Partial Repet.
Alternation
Stimulus Transition
B.
Response-Repetiton Benefit (%)
20
16
12
8
4
0
-4
-8
-12
-16
-20
Task Repetition
Task Switch
Repetition
Partial Repet.
Alternation
Stimulus Transition

Figure 5


Integration Threshold
P-
E
C
Base Level
integration
Integration Threshold
P+
E
C
Dimensional Priming
Base Level