Acquisition and Control of Voluntary Action

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Abstract

This chapter deals with the cognitive underpinnings of voluntary action, here defined as goal-directed behaviour. It is delineates how voluntary action emerges through the automatic acquisition of bilateral associations between cognitive codes of movement patterns and sensory movement effects. Once acquired, these associations can be used in the backward direction to choose movement patterns by activating codes of intended outcomes (the Lotze-Harleß principle). Actions are planned by specifying the features of intended outcomes, binding the activated feature codes, and integrating them with features of anticipated trigger stimuli. Integrated action plans are then carried out automatically as soon as the trigger stimulus is encountered.

Defining Voluntary Action

William James (1890), one of the grand old men in cognitive psychology, was not particularly enthusiastic about definitions. A good (though not the best known) example is the way he introduces readers of his famous *Principles of Psychology* into chapter XXVI on the *Will*: "Desire, wish, will", he wrote, "are states of mind which everyone knows, and which no definition can make plainer" (Vol. 2, p. 486). However, he does go on to provide a little more detail: "We desire to feel, to have, to do, all sorts of things which at the moment are not felt, had, or done. If with the desire there goes a sense that attainment is not possible, we simply *wish*; but if we believe that the end is in our power, we *will* that the desired feeling, having, or doing shall be real; and real it presently becomes, either immediately upon the willing or after certain preliminaries have been fulfilled." (James, 1890, Vol. 2, p. 486).

As far as cognitive psychology in concerned, these terms are outdated and no longer in use, as are other terms so obviously tied to introspective experience. However, James' basic approach to understand voluntary action as goal-oriented movement, directed toward anticipated action effects, is perfectly consistent with the perspective of more recent authors. For example, according to Ach (1910, p. 256) a voluntary action "represents the realization of the anticipated concrete content of an act of will" (translated by the author); Miller, Galanter, and Pribram (1960) describe voluntary action as movements that are steered towards anticipated goals by superordinate plans; Heckhausen (1991, p. 12) believes that "an action comprises all activities which pursue the same 'goal idea'"–and many more examples of this sort can be found in Pongratz (1984) and Hoffmann (1993).

In contrast to James, however, later authors often did not require goals or anticipated action effects to be conscious. Tolman (1932) already argued that, if diagnosed objectively, rats–commonly unsuspected to enjoy conscious experiences–can show purposive behavior as well as humans can. In the same vein, Frith (1992) has argued that some typical delusions exhibited by schizophenics might reflect a tendency to attribute their own (voluntary) actions to external forces, suggesting that one does not need to be conscious of one's action goal to act voluntarily.

All in all, an acceptable working definition of voluntary action within the domain of cognitive psychology seems to require the concept of an *action goal*, that is, of some anticipatory cognitive (not necessarily conscious) representation of an intended event that somehow mediates the organization and execution of appropriate movements. In the following, I will concentrate on the "somehow" in this definition. I will begin with pointing out that performing a voluntary action presupposes knowledge about action→effect relationships, and I will describe how this knowledge might be acquired. Then I will describe in some more detail that and in which sense action control is anticipatory, before I go on to consider how people actually control their actions. I will conclude with some critical arguments regarding the usefulness of voluntary action as a scientific concept.

Acquisition of Action Effects

According to our working definition a voluntary action is a goal-directed activity and, therefore, necessarily oriented towards a future event. Logically, this implies some kind of anticipatory representation of the intended action outcome and some movement pattern carried out to actually produce the outcome. The emergence of outcome representations is easy to understand: We may simply remember a previous event that we have liked and that we now want to enjoy another time. But, as James (1890) has pointed out, a desire without appropriate action remains a wish, which poses the question of how one knows which action is required to attain a particular goal. This is not just a problem with ambitious and complex goals, such as the desire to get rich and famous, but also of relevance with the most common activities, such as reaching for a cup of coffee or tying a shoe–just try to explain in detail *how* you do it! So, the crucial question is, given a particular goal, how do we select the appropriate movement pattern? Or, put differently, how do we know what a particular movement is good for?

Lotze and Harleß suggested some interesting answers to these questions. In Lotze's (1852) view, the will has no direct access to the motor system and, therefore, cannot select particular movements directly. All it can do is, in a sense, to register the relationship between a given movement and those internal states of the central nervous system that accompany and/or follow it. Once knowledge about these relationships has been acquired, an intended movement can be chosen by re-activating the internal state that is known to be associated with it.

Harleß (1861) followed the same line of reasoning but presented a more detailed model of how movement-related knowledge is acquired, stored, and used later on. He postulates two stages in the emergence of voluntary action. The first stage consists of the acquisition of bilateral links between movement codes and those sensory codes that are activated as a consequence of performing the movement. That is, the very fact that a sensory code s is activated at about the same time as a motor code m leads to a bilateral association between the two $m \leftrightarrow s$. Obviously, this associative structure represents the knowledge that performing m produces s, a simple form of knowledge about possible means and associated ends. According to Harleß it is these associative structures that underly voluntary action that, on a second stage, makes intentional, goal-directed use of the collected knowledge. Indeed, as the associations are assumed to be birectional, re-activating the representation of a particular action effect results in the automatic activation of the associated movement pattern, so that merely "imagining" an intended action effect envokes the movement capable of producing it without (much) further ado.

This is no doubt a very simplified picture. For instance, it neglects the possibility that performing the same movement under different circumstances produces different effects, such kicking with one's foot against a ball versus a stone of the same size. To be useful, knowledge about possible actions needs to incorporate not only information about movements and effects but about context conditions as well (Hoffmann, 1993), an issue I will get back to later on. Moreover, Lotze and Harleß were mainly concerned with very simple actions like moving one's finger or hand, which produce effects that are mostly body-related (proximal) and immediate, such as kinesthetic and tactile feedback. However, more complex actions often produce effects that are much more distant in terms of both space (distal) and time–just think of preparing a meal or taking a trip. This suggests that action representations include information about all kinds of action effects (proximal *and* remote, immediate *and* delayed), that is, codes of any event that an actor experienced to follow from his or her action (Hommel, 1997, 1998a).

The assumption that all kinds of action effects are functionally equivalent gives us the opportunity to study the acquisition of knowledge about means and ends even in adults and in the laboratory. For instance, Hommel (1996) had people perform simple keypressing actions that were followed by tones of a particular frequency, such as a single keypress followed by a low tone and a double press followed by a high tone. According to the framework of Lotze and Harleß the repeated experience of a tone s following a motor pattern m (responsible for the keypress response) should lead to a bilateral association $m \leftrightarrow s$, so that Hommel's (1996) subjects should have acquired two such association, $m_1 \leftrightarrow s_1$ and $m_2 \leftrightarrow s_2$. If so, and if those associations are actually bilateral, there should be a way to activate motor pattern m by activating the sensory code s. This is what we did in the study: After subjects have had some experience with the keypress-tone relationships, tones were presented not only as effects (i.e., after the keypress) but also as primes (i.e., briefly before the visual stimulus). There are two possible conditions, a *congruent* one in which the prime consists of the same tone as the effect (e.g., high tone → double press → high tone), and an *incongruent* condition where prime and effect tones are different (e.g., low tone → double press → high tone). We expected that presenting a tone as a prime would lead to some activation of the (presumably) associated movement, which should speed up response selection in congruent conditions but impair performance in incongruent conditions. Indeed, we obtained such congruence effects across a number of different versions of this task, supporting the idea of automatic acquisition of bilateral associations between movement codes and codes of their effects–even if these effects are completely arbitrary.

The same conclusion can be drawn from a study of Elsner and Hommel (2000). Again, people were confronted with arbitrary but consistent relationships between their keypressing actions and keypress-contingent tones. Then, in a second phase, they were asked to perform free-choice responses to tone stimuli. That is, they heard a randomly determined tone and pressed a deliberately chosen left or right key. As expected, the choice was not random but depended systematically on the type of tone. For instance, if previously the left key produced a low and the right key a high tone, hearing a low tone made the subjects to press the left key more likely than the right key, and vice versa. This was true even when the free-choice task was performed under high time pressure and under heavy workload from a secondary task, which rules out that the response bias resulted from a strategy. Apparently, if we manage to experimentally induce some activation of an internal representation of a possible action effect, this leads to at least some activation of the motor pattern that is known to this produce this effect. This does not yet prove that action effect representations play a crucial role in everyday voluntary action (an issue dealt with in the next section), but it demonstrates that action-effect relations are automatically acquired and suggests that the acquired knowledge includes bilateral associations between codes of movements and their perceivable effects.

The automatic acquisition of action effects is not restricted to simple binary-choice tasks. For instance, Sebald, Hoffmann, and Stöcker (1999) investigated the role of action effects in a serial learning task, where subjects were to acquire complex sequences of keypresses. When each keypress produced a particular tone, sequence learning proceeded much more quickly than in control conditions without artificial action effects. Apparently, the subjects were able to integrate their responses with the tones and then simply learned the "melody" they produced. Further evidence for an important role of action effects in serial learning has been reported by Zießler (1998).

One limitation of the studies discussed so far is that with one exception (Zießler, 1998) they all used auditory effects only. The obvious reason is that the manipulated action effects were task-irrelevant and, thus, could have been simply overlooked if presented in a less salient modality like vision, say. But there are reasons to believe that action effects of other modalities can be acquired as well. Apart from demonstrations with visual effects (Hommel, 1993; Zießler, 1998), a recent study of Beckers and De Houwer (2000) shows that electrocutaneous action effects are also learned. In a study phase, they had subjects to move a button up or down in response to the grammatical category (verb vs. noun) of neutral words. One of the two responses was consistently followed by a mild electroshock, this way creating an emotionally neutral (no shock) and an unpleasant (shock) action effect. In the test phase, the task was the same but the stimuli were now words with positive or negativ emotional valence. As expected, people responded more quickly if the valence of the stimulus matched the (apparently acquired) valence of the response, hence negative words were responded to more quickly with the response followed by a shock while the opposite was true for positive words. This means that actions acquire the emotional valence of their consequences. The same conclusion can be drawn from a study of Van der Goten, Lammertyn, De Vooght, and Hommel (in press). In one experiment of this study, subjects performed two keypressing tasks in a row, with the second keypress triggering the visual presentation of a smiley or a grumpy (each mapped onto one of two keys). As it turned out, preparing the smiley-producing keypress facilitated the processing of emotionally positive words in the other task, whereas preparing the grumpy-producing response primed words with a negative valence. Again, this suggests that the representations of movements are integrated with codes of the effects they produce.

The extension of the Lotze-Harleß principle into the domain of emotions has particularly interesting theoretical implications in showing that the principle is consistent with, and can be applied to, both cognitive, rationalistic action theories and more motivationally based pleasure-and-pain approaches. That is, whether we see action as being directed towards rational goals or as driven by a hunger for lust, the underlying cognitive mechanism may be exactly the same. In either case the first step in the emergence of voluntary action would be the acquisition of associations between movement patterns and their consequences–be they sensory or emotional, if one wishes to make this difference at all[1].

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[1] Indeed, even if we accepted a motivational (e.g., behavioristic) point of view it is difficult to tell whether individuals maximize their pleasure (whatever this may be) or their *perception* of pleasure. In the latter case one would have a hard time to explain why the perception of pleasure–the cognitive representation of input from the autonomous nervous system–should fall into a completely different theoretical category than the cognitive representation of input from other, sensory systems. This is especially obvious in the case of perceiving the presence or absence of pain.

Anticipatory Control of Voluntary Action

According to our considerations the automatic acquisition of movement-effect associations is a necessary precondition for voluntary action to occur, as they make the anticipation of action outcomes possible and, thus, enable the actor to select movement patterns with respect to intended action goals. Indeed, the available evidence strongly suggests that codes of movements and of their perceived consequences are linked in a bilateral fashion. However, the mere availability of such associations is by no means sufficient, nor does their mere existence prove that they are indeed used and functional in everyday action control. So, how can we know that voluntary action is actually selected and controlled by integrated action-effect structures?

One piece of evidence comes from a study of mine on the so-called Simon effect (Hommel, 1993). Subjects responded to low- and high-pitched tones by pressing a left- vs. right-hand key. The location of the tone was not relevant but tones appeared randomly to the left or right of the subject. Conditions like that are known to yield better performance (faster and less error-prone responses) if stimulus and response correspond, hence if the tone signaling the left response appears on the left or if the tone signaling the right response appears on the right side–the Simon effect (for an overview, see Lu & Proctor, 1995). According to the action-effect framework this should be so because the in this case spatial features of the stimulus overlap with those of the action effect. As any action, a keypress should be cognitively represented by codes of its sensory consequences: kinesthetic feelings in the active arm and index finger, visual impressions from the moving finger, auditory input from the moved key, and so forth. In case of a left-hand response, many or all of these events take place to the left of the subject, so that their cognitive representations share the feature LEFT. If then the actor perceives a stimulus on the left side, its representation also shares the feature LEFT and thereby partly specifies, in a sense, the appropriate action goal (i.e., the intended action effect). However, if the stimulus appears on the right side, the goal of the incorrect (right) response would be specified. This leads to response conflict, hence the Simon effect.

If this scenario is a correct description of how action planning works, one should be able to modify the Simon effect by changing the actor's action goal, and this was the aim of the Hommel (1993) study. In two experimental groups, each key was connected to a red light on the *opposite* side, so that pressing the left key caused a brief light flash on the right side and pressing the right key produced a flash on the left side. Although the two groups performed exactly the same task with identical stimulus-response and response-light mappings, their instructions differed. One group of subjects was asked to "press the left/right key" in response to the low/high tone (the *key instruction*) , whereas the other group was instructed to "flash the right/left light" accordingly (the *light instruction*). The idea was that people with a key instruction would specify their action goals in terms of key location whereas people with a light instruction would specify their goals in terms of light location. As these locations were always opposite to each other, the Simon effect should be completely reversed: A left-side stimulus, say, should facilitate left-hand keypresses under key instruction but *right*-hand keypresses under light instruction–simply because with light instruction the goal of a right-hand keypress should be flashing a left-side light. In other words, not the spatial congruence between stimulus and physical action should matter but that between stimulus and intended action effect. And this is exactly what happened: While people in the key group produced a typical Simon effect (i.e., better performance with stimulus-key correspondence) the light instruction completely reversed the result pattern. Obviously, people not only pick up relations between their movements and movement-contingent sensory events but they also make use of these relations to formulate their action goals and select the appropriate action. How they make use of them can be manipulated by the way an action is presented and described, suggesting that the usage is controlled by, and thus reflects, the actor's intentions.

Further evidence for the intentional use and the functional role of action-effect representations in voluntary action planning comes from a study of Kunde (2000). In Kunde’s experiments subjects prepared, in each trial, one of four possible keypressing responses, which were all followed by a particular tone (i.e., each of two tones was mapped onto two responses). When the stimulus then signaled the already prepared response, reaction times were faster as compared to unprepared conditions. More interesting, however, were the trials where the stimulus signaled another, unprepared response. Although responding was generally slower, the slowing was much reduced when the required response shared its effect tone with the prepared response. This means that preparing a response must have been associated with an activation of the just acquired effect-tone representation, which again produced some priming of the other response associated with this effect tone.

Mechanisms of Action Control

Up to now we have seen that people do not only acquire bilateral associations between movement and effect codes but also actively use these associations to control their voluntary actions. But how do they actually do that, what are the mechanisms that transform knowledge about possible means and ends into goal-directed action? In the following, I will deal with this question in three steps. First I will set the stage for discussing possible mechanisms by addressing the *when* of action planning. It is commonly assumed that action planning processes intervene between perceiving a stimulus that triggers the planning on the one hand and response execution on the other. This perspective leads to the view of intentional processes or the will as a rational instance that, in a way, decouples actors from their environment to make their behavior less stimulus driven. However, I will argue that this view is probably incorrect and misleading. Second, I will describe in some more detail how action goals are specified and then, third, how they are transformed into overt action. Finally, I will outline that and how intentional processes prepare the cognitive system for voluntary action by the binding of action plans to trigger conditions. I hasten to add that the emerging picture should be treated as a first, preliminary sketch only, based on some, but yet insufficient empirical evidence.

Planning an Action

According to a common conception in cognitive psychology human information processing starts with some stimulus information, which is transmitted to increasingly complex processing stages, before eventually some appropriate response is computed. Although this view has shown to be enormously successful in generating a whole wealth of empirical findings, it more or less directly takes over the behavioristic scheme of action as stimulus-triggered *re*-action, which again does not seem to provide an apt characterization of what higher animals really do (Dewey, 1896; Hommel, 1998a; Hommel & Elsner, 2000). One possibility to account for the fact that actions are commonly *not* fully determined by our environment is to have some instance intervene between perception and action. In earlier approaches it was the job of the *will* to evaluate the products of perceptual processing and to select the appropriate response (e.g., Donders, 1868), whereas modern approaches prefer terms like *central executive* (e.g., Baddeley, 1986) or *supervisory attentional system* (e.g., Norman & Shallice, 1986). However, apart from terminological preferences, the question is whether intentional processes actually accompany voluntary action and control it on-line, so to speak.

An alternative conception has been suggested some time ago by Sigmund Exner (1879). In his chapter on attention he reports about some introspective observations while making a speeded hand movement in response to the onset of a visual stimulus. Exner noticed that long before the stimulus comes up, he had already set himself into some kind of state that ensured the response would be carried out efficiently and as intended. Evoking that state is a voluntary act requiring attention, so he argues, but once the state is created, the response is actually involuntary, that is, no further effort of will is needed to translate the upcoming stimulus into the response. Thus, what makes an action voluntary would not be the intervention of the will between stimulus perception and response preparation, but the intentional preparation of the cognitive system to respond to a particular situation in a particular way. In a sense, while being carried out even the most voluntary action would be involuntary (i.e., governed by previously enabled automatic processes)--the cognitive system works like a prepared reflex (Hommel, 2000).

Exner was not the only one to challenge the idea that the will intervenes between stimulus processing and response execution. In a series of reaction time experiments, Münsterberg (1889) observed that even with unpracticed tasks motor responses often begin before their stimulus is completely identified and consciously perceived–an assumption that is nicely supported by recent investigations of Neumann and Klotz (1994) and Eimer and Schlaghecken (1998). Similar considerations were put forward by Marbe (1901) and his Würzburg colleagues from a more phenomenological perspective. To study acts of response-related decision, Marbe had his subjects respond to all sorts of questions, ranging from weight judgments to arithmetic problems. However, when he asked them to describe the processes that intervene between hearing the question and giving the response, the answers were not very informative: some description of the stimulus or the response, but nothing that would refer to a decision. Among other things, it was this outcome that led adherents of the then-evolving Würzburg school to believe that task instructions are transformed into a cognitive task set before, but not as a result of, stimulus presentation.

These and other findings suggest that intentional processes make actions voluntary by preparing and binding them to situational conditions, not by cutting them off from environmental information, as the processing-stage framework suggests (Hommel, 2000). In particular, they support the idea that action planning is usually not triggered by, but precedes, and often prepares for, stimulus perception.

Specifying the action goal

If action planning precedes the stimulus designated to trigger the planned action, something has to be done before that stimulus arrives. According to the scheme proposed above this something consists in specifying the action goal. An action goal, in this scheme, consists of cognitive codes of the features the intended goal should have. Such a goal might be simple, such as with the intention to press a key at a particular location. In that case the intended action effect might be described, and cognitively represented, as the experience of the key being depressed, which again may be mediated by the perception of kinesthetic, tactile, auditory, and/or visual feedback. Codes of these intended sensory action effects would make up the action goal (Hommel, 1993). According to the Lotze-Harleß principle all these codes are associated with the motor patterns from which they typically originate and, as the associations are bidirectional, activating the feature codes leads to the activation of the associated motor codes. It is these activated motor codes that make up what one may call the motor program (Elsner & Hommel, in press).

Action plans will often be more complex than just pressing a key on a computer keyboard–even though both subjects in psychological experiments and psychologists writing reports about the outcomes spend a lot of time doing exactly this. On the one hand, this brings in a whole number of additional problems: The abstract plan of making a trip needs to be transformed into a sequence of more detailed component plans, the where’s, how’s, and when’s need to be specified, and the plan sequence needs to be carried out in the correct order. On the other hand, however, there is no reason why the underlying mechanisms should differ from those involved in planning a keypress. That is, once the sequence of subgoals of an abstract plan is specified, the planning of each individual subgoal proceeds by activating the cognitive codes of goal features which then spread their activation to associated motor patterns.

Integrating the Action Goal

On first sight, it may seem that specifying the features of the intended action goal is sufficient to prepare an action–after all, according to the Lotze-Harleß principle feature activation should induce the direct activation of the corresponding motor structures. However, it is not overly realistic to assume that people are involved in only one action at a time: We speak while walking, eat while reading, and make notes while listening to a lecture. Now, if it is true that action control consists in activating the features of the intended goal and holding them activated until the action is successfully completed, performing two temporally overlapping actions requires the concurrent activation of the goal features for *both* actions. If the two actions have nothing in common this does not seem to pose a problem. For instance, it is difficult to see why activating a sequence of articulatory goal features, like in a verbal utterance, should have any implication for, or impact on, planning a grasping movement towards a visible object. Assume, however, two spatially defined actions are planned or carried out at the same time–say, turning the body to the right while pointing to the left. Planning these actions would require activating the spatial code LEFT *and* the spatial code RIGHT, this leading to confusion about which movement should go left and which should go right (see Figure 1).

****** Figure 1 ******

These so-called *binding problems* (see e.g., Singer, 1994; Treisman, 1996) are typical for systems with representations made up of multiple components. One way to solve such problems is to indicate, for each given component, to which superordinate structure they belong–for instance, by synchronizing the firing behavior of the cell populations representing the same event (Singer, 1994). In our context, this means that, in addition to activating the feature codes specifying a particular goal, a mechanism is needed to bind and integrate these codes into a coherent action plan. Indeed, Stoet and Hommel (1999) have shown that planning an action including a particular spatial feature impairs the concurrent planning of actions with overlapping features, suggesting that integrating a feature into one plan makes it temporarily less available for making other plans. Planning an action has even been shown to affect the perception of action-related stimulus events. For instance, Müsseler and Hommel (1997) observed that planning a spatially defined action makes it more difficult to perceive a feature-overlapping stimulus, such as a left-pointing arrow that appears while preparing a left-hand keypress. Like the findings of Stoet and Hommel (1999) this suggests that integrating a spatial feature (such as LEFT) into an action plan makes this feature less available for representing other LEFT events.

****** Figure 2 ******

Apparently, action planning does not only involve the specification of the features the intended action outcome should have, but it also requires the temporary integration of those features into coherent action plans–at least if more than one action plan is in effect at a time. This does not necessarily require additional executive control mechanisms. As shown in Figure 2, feature binding may be an automatic consequence of holding the to-be-bound feature codes active for some minimal time. That is, it may be an inherent property of the cognitive system to bind all the codes whose current activation level reaches a particular integration threshold. As we have seen, this may hold for the integration of movement and effect codes as well as for action-feature codes that refer to the same action. Evidence discussed in the next section suggests that it is also likely to hold for codes of action features and of context stimuli.

Contextualizing the action goal

If we assume that action planning commonly precedes the stimulus that triggers the execution of the action, an action plan must include some specification of the context conditions under which it should be carried out–it needs to be *contextualized*. Preliminary ideas of how this might be done have been discussed by several authors. Allport (1980) has argued that actions are controlled by previously set-up condition-action rules or productions in the sense of Anderson (1982)–an an assumption that has been taken up by Meyer and Kieras (1997) in working out their EPIC model. Very similarly, Prinz and Neumann (Neumann & Prinz, 1987; Prinz, 1983) proposed that initiating an action is mediated by conditional operations that are intentionally prepared, but automatically performed. Also, most of the now rediscovered interest in task-switching performance (see the overview by Monsell, 1996) is strongly motivated by the idea that processes responsible for implementing task-specific initiation rules can be empirically and theoretically dissociated from the processes applying those rules. And even investigators of long-term planning processes like Gollwitzer (1996) have argued that, once an action plan is formed, it will be reactivated and set in effect automatically if it already includes, and thus anticipates, the corresponding environmental situation.

Contextualizing an action plan need not require overly complicated mechanisms, as suggested by recent findings of a study of mine (Hommel, 1998b). In each trial of this study, people performed two left-right keypressing responses in a row. The identity of the first response (R1) was signaled by a precue, but the subjects had to withhold responding until the first stimulus (S1) appeared. Although S1 varied in shape, color, and location, subjects were only to react to the presence of S1, hence all S1 features were irrelevant and could be ignored. A second later another stimulus (S2) would appear, signaling a binary-choice response (R2) to its shape, say. The important observation was that performance on R2 depended on the relationship between S1 and R1 on the one hand and between S2 and R2 on the other. For instance, subjects showed better performance if the combination of S1 and R1 either matched that of S2 and R2 (e.g., X→left key, X→left key) or completely mismatched (e.g., O→right key, X→left key), as compared to conditions with a partial match (e.g., O→left key, X→left key). However one accounts for this effect in detail, its existence suggests that the features of S1 and of R1 were bound together in a way that affected the subsequent processing of other stimulus and response features. This is the more interesting as the features of S1 were completely irrelevant, so that binding was not necessary at all. Nevertheless, task relevance did have an indirect influence on S1-R1 binding. Namely, if R2 was signalled by the shape of S2, the relationship between R1 and S1 shape yielded stronger effects than that between R1 and S1 color, while the opposite was true if R2 was signalled by the color of S2. In other words, if a particular stimulus dimension was relevant for the task (although only for the second part), features on this dimension were integrated more strongly with response features.

How might these admittedly rather complicated observations of Hommel (1998b) be applied to the issue of plan contextualization? Now, the findings suggest that the features of a stimulus that accompanies a particular response are more or less automatically bound to the features of this response. Apparently, this binding is restricted to features that are of some relevance for the task, irrespective for which the part of the task. This again fits well with the simple integration mechanism sketched in Figure 2. If some stimulus or response dimension gets task relevant, the base level for features varying on this dimension may be temporarily increased, such as for stimulus shape or color and response location in the Hommel (1998b) study. Accordingly, the corresponding features will get automatically integrated if they only occur at about the same time. Once they are integrated, activating the code of one feature will spread activation to the other, just like in the case of movement and effect codes. Now, consider what happens during everyday action planning. The prospective actor will in some way specify the required features of the intended action effect, such as when imagining oneself to go to work. At the same time, the actor will also think of the required trigger conditions, be they specified in time (“I have to go at 7 o’clock”), in space (“after leaving the door”), or by preceding events (“after I have finished my breakfast”). In terms of cognitive processing, these activities imply that codes of the action-effect features and codes of the trigger-stimulus features are activated at the same time, whether through external stimuli (e.g., when reading a reminder) or internal processes (e.g., when imagining or talking to oneself). As a consequence, the corresponding features will be integrated into a common action plan. If then the trigger event occurs its internal codes will get activated, and this activation is spread to the other, action-related components of the action plan. If there is no strong competition through other ongoing plans, the planned action is carried out.

To summarize, planning a voluntary action requires the specification of the action goal (i.e., the features of the to-be-produced event) and the integration of these features together with features referring to the trigger conditions. The integration part of this process may be taken care of by rather simple, automatic processes and, thus, is unlikely to require much intellectual work. The same is true for the actual execution, which will often be triggered by anticipated environmental stimuli and context conditions. So, what seems to be really and purely intentional about voluntary action is only the selection of the intended event, the action goal, the activation of which then primes the relevant feature dimensions (which then control integration) and the corresponding motor patterns (by means of movement-effect associations).

Voluntary Action, a Useful Concept?

In everyday life, the concept of voluntary action plays an important role. People are attributed less responsibility for bad habits with harmful consequences for everybody, like smoking, when they declare their “dependence” or “addiction”. Criminals receive a more favorable judgment both in the community and before court when claiming that they “didn’t intend” to commit a given crime. And politicians try to get a better opinion when they explain their failures as being done “by mistake”. One can argue about whether we should really think that people are less responsible for their dependence, the circumstances, and their mistakes than for their truely voluntary actions, but my point here is that the common sense concept of voluntary action works. The question is whether the concept also works scientifically, especially in cognitive psychology. And here I have my doubts.

Let us take the criterion of goal-directedness. Assume, for instance, you are asked to name the color of stimulus words that happen to consist of color names, the so-called Stroop test. So, you see the word RED written in green ink and you are expected to say “green”. Although this task will be manageable, you will make some errors and sometimes say “red”. Is this an involuntary action? Sure you know that the response was not correct, and in that sense you “didn’t intend” to say “red” to a green word. But, on the other hand, without the intention to respond to color-related stimuli by saying color words you will hardly ever have said “red” in this context at all. In that sense, your response very well reflects your intention, and it is completely dependent on it. So is it a voluntary action? If you object that this example is artificial and stretched, just think of a robber who “didn’t intend” to shoot the cop when being surprised during an armed robbery. Or consider whether it would be correct to say that smoking or taking other drugs is *not* goal-directed.

The problem I am addressing here is, of course, neither new nor restricted to the concept of voluntary action. As long as psychology was concerned with conscious experiences, as in the days of James, there was some common ground for the laymen and the scientific concept of voluntary action or, for another important example, attention. The commonality laid in the phenomenon–the experience the laymen and the scientist shared–and the explanatory language, while the analytical methods differed. However, modern cognitive psychology is no longer concerned with conscious experience at the explanatory level. Instead, it has become something like functional biology and explains psychological phenomena in terms of systems and processes, often with reference to the physiological and neuroanatomical underpinnings. From this perspective it is (and should be) still possible to refer to the laymen concept by trying to explain, at a more basic, functional level, what is going on when a person is said to perform a voluntary action. And this is what I have attempted to do here. However, saying that, for instance, process x is subserving the performance of such an action in such and such a way does by no means exclude that the same process is doing exactly the same thing in the course of an involuntary action–however defined. In fact, we have already seen evidence suggesting that the processes underlying voluntary action are subserving involuntary action as well: action goals can be activated (Hommel, 1993) and even induced by irrelevant stimulus features (Elsner & Hommel, 2000), and feature integration seems to happen automatically (Hommel, 1998b). That is, at the explanatory (how) level prefered by cognitive psychology volition just doesn’t make a difference. Therefore, it may be wise to leave the voluntary action concept what it is: a useful everyday word with a fuzzy meaning, but not a scientific term.

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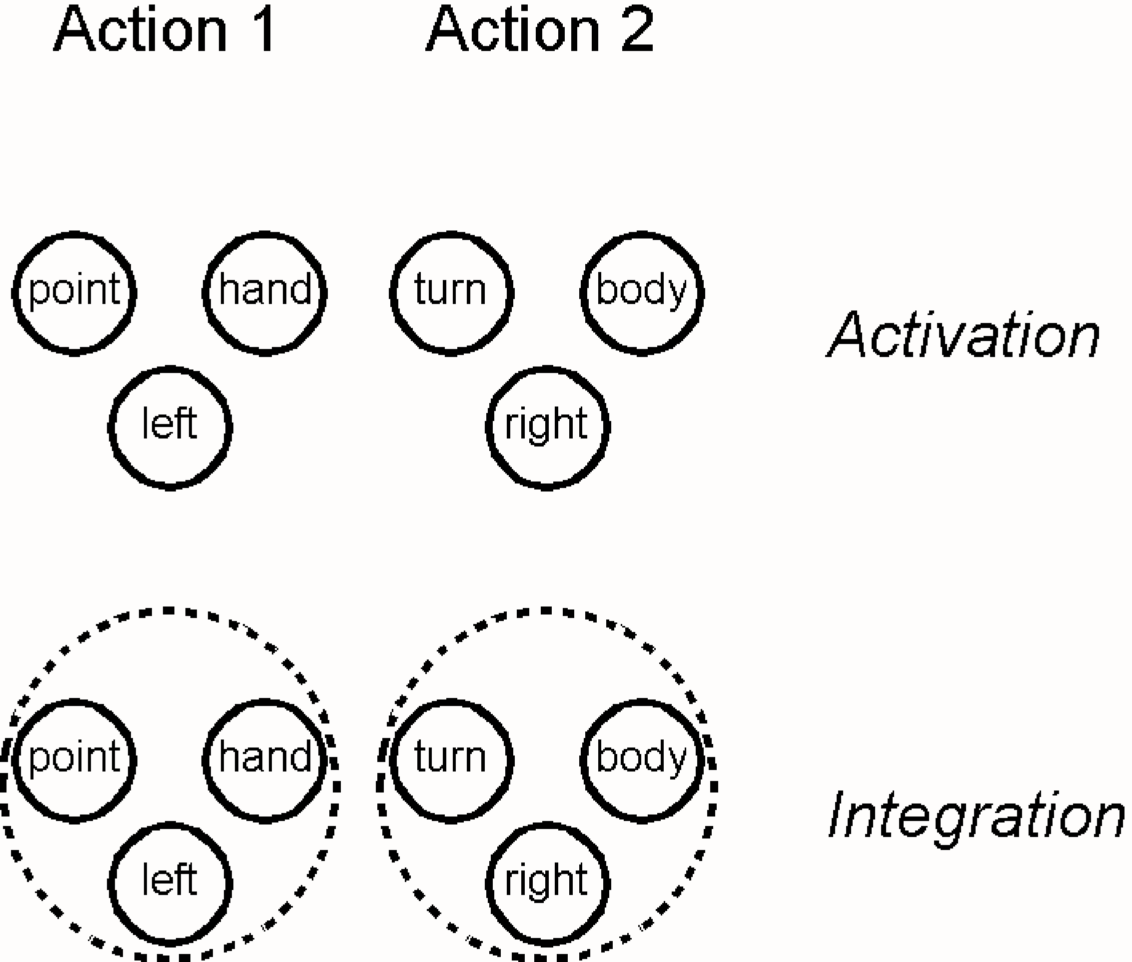
Figure Captions

Figure 1: If features of more than one action are activated at the same time (see top panel), a feature-binding problem exists. It might be solved by integrating the features belonging to the same action plan (see bottom panel).

Figure 2: A simple integration mechanism. Features are automatically integrated if, and only if, the activation level of their codes reaches an integration threshold. As long as the activation of feature codes (here of codes F_1 and F_2) varies below threshold, no integration occurs (see P-). However, if the dimension of the 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 features will be bound automatically.


Action 1
Action 2
point
hand
left
turn
body
right
Activation
point
hand
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turn
body
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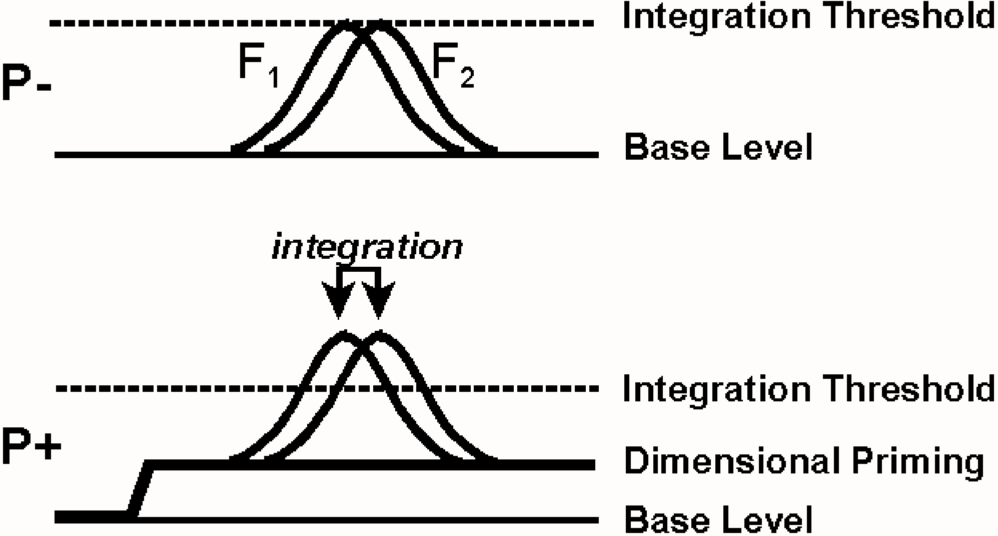
Integration


Integration Threshold
P-
F1
F2
Base Level
integration
Integration Threshold
P+
Dimensional Priming
Base Level