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Categorization of Action Slips

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A slip is the error that occurs when a person does an action that is not intended. In this article I examine several collections of slips, primarily of actions, with the aim of devising a theoretical explication. A theory of action is outlined in which an action sequence is represented by a parent schema and numerous child schemas, in which several action schemas can be active at any one time, and in which each schema has a set of triggering conditions and an activation value. The path from intention to action consists of the activation of the parent schema that corresponds to the intention, the activation of child schemas for the component parts of the action sequence, and then the appropriate triggering of schemas when the conditions match those required for their operations. This action system allows slips to be organized into three major categories and a number of subcategories. The three major categories of slips are: (a) errors in the formation of the intention (which includes the subcategories of mode and description errors); (b) faulty activation of schemas (which includes the subcategories of capture errors, data-driven and associative activations, loss of intention, and misordering of action components); and (c) faulty triggering (which includes the subcategories of spoonerisms, blends, intrusions of thoughts, and premature triggering).

A slip is a form of human error defined to be the performance of an action that was

not what was intended. Slips can often be interpreted. They often appear to result from conflict among several possible actions or thoughts, from intermixing the components of a single action sequence, or from selection of an appropriate act but in some inappropriate way. From an analysis of slips of action it is possible to construct the outlines of a theory of action that suggests how an intention is represented and acted upon.

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One of the first large collections of verbal slips was put together by Meringer (1908; Meringer & Mayer, 1895/1978). The best early theoretical account was provided by Freud (1901/1966), who made use of Meringer's collection. Freud's analyses made important contributions to our understanding of the mind. Freud's contribution can be reinterpreted in modern terminology by separating the two different aspects of cognitive machinery that he made use of: processing

and knowledge. Freud believed that slips resulted from competition among underlying mechanisms, often working in parallel with one another and almost always beneath the consciousness of the owner. The resulting notions were of mental operations controlled by a quasi-hierarchical control structure, with parallel activation of thoughts and memories and with conscious access to only a limited amount of this activity. The ideas are sophisticated even for today's theorists, who only recently have introduced the differences between conscious and subconscious processing into their models of cognitive functioning and who are just beginning to develop notions of independently operating computational units. Freud also was concerned with the particular knowledge contents of the memories and beliefs of his patients, but these analyses are not required for the understanding of the mechanisms that underlie slips.

Slips are indeed compelling sources of data. To Freud, the interpretations of some were clear, "for the meaning in them is unmistakable, even to the dullest intelligence, and strong enough to impress even the most critical judgment" (Freud, 1924, p. 59). It is indeed true that slips appear manageable and that they cry out for interpretation. The examination of any large collection of slips reveals that they can be categorized and that they fall into patterns. (See, for example, the collection and categories of verbal slips in Fromkin, 1973, Appendix.) However, the meaning in them is not at all clear; their categorization and interpretation are theory dependent, yet contemporary theories of cognitive behavior are not really up to the task. Several workers have tried to categorize human error in terms of behavioristic criteria (errors of commission, of omission, of substitution). These classifications do not aid in understanding the underlying mechanisms. Moreover, they quickly become large and unwieldy. A complete error theory seems likely to require autonomous, subconscious processing, with intentions, past habits, thoughts, and memories all playing some role in corrupting the intended behavior.

Consider the following slip. I was leading a conference discussion for a group of papers

on the topic of "Representation of Knowledge." In my coverage of one of the speakers' presentation, I said, "This tells us nothing of the reputation [pause] *representation* of the information." A clinical (Freudian) interpretation is easy to perform; the slip revealed my underlying concern about the reputation of the speaker. But note that the slip itself did not occur at a random time: The hidden intent apparently was able to select just the right opportunity to reveal itself, a situation where the syntactical and phonological components would match properly. The words *reputation* and *representation* share a common ending and a common beginning and are the same part of speech. The erroneous sentence is just as grammatical and meaningful as the intended sentence. What mechanisms can account for these aspects of slips? These different aspects of a slip point out an important point: Most slips have multiple causes. Many sources of information are likely to be interacting to give rise to any particular action. When the act is an error, it is apt to be the result of numerous underlying forces, so that the resulting slip is multiply determined and consistent with a number of constraints and explanations.

Analyses of verbal slips indicate that the pronunciation of words is not a unitary concept associated with the words. Otherwise, once having started a word, we would go all the way through with it. But people say such things as *canpakes* for *pancakes* and *relevation* for *revelation*; or they interchange sounds among several words, as in *the sweeter hitch* instead of *the heater switch*. One form of error is a blend: when a person is undecided about two words, out comes a mixture, as in *momentaneous* for the mix of *momentary* and *instantaneous* (all these examples come from Fromkin, 1973, Appendix). There appear to be notions of individual parts of an action or of an utterance, perhaps differentially activated, waiting to be picked up and executed. As with the slip of *reputation* for *representation*, slips probably have several contributing causes, with the actual word selection being influenced by a combination of syntactical considerations, meaning, and phonological selection from the set

of possible words, as well as by activation of underlying motives and plans.

Verbal slips have been widely studied (see the collections of articles in Fromkin, 1973, 1980). In the present article I concentrate on slips of actions rather than of words. These have not been so thoroughly studied as verbal ones, but they have been noted. One form of action slip is the performance of a well-formed habit in inappropriate circumstances, as in the report by William James (1890) that

very absent-minded persons in going to their bedroom to dress for dinner have been known to take off one garment after another and finally to get into bed, merely because that was the habitual issue of the first few movements when performed at a later hour. (p. 115)

Other action slips result when a thought that was not intended to be voiced or performed gets done anyway. Sometimes the complementary slip occurs. Having thought about the need to do some action or to say some utterance, the person does not do it but believes that it has been done (or, at least, later remembers it to have been done). In one case, thoughts cause actions, in the other, thoughts replace actions.

One interesting aspect of slips is people's ability (or inability) to detect them. Many slips are caught at the time they are made. Sometimes they are caught just prior to their occurrence, but with insufficient time to prevent the act, or at least the initial stages of the act. For a slip to be started, yet caught, means that there must exist some monitoring mechanism of behavior—a mechanism that is separate from that responsible for the selection and execution of the act.

Outline of an Activation-Trigger-Schema System

The proposed model, an activation-trigger-schema system (ATS), assumes that action sequences are controlled by sensorimotor knowledge structures: *schemas*. A schema is an organized memory unit, much along the lines proposed for perception and memory (Norman & Bobrow, 1976; Rumelhart & Ortony, 1977). The extension of these ideas to include motor actions seems

natural, both from the demands of the situation and from historical precedent (Head originally introduced the term *schema* specifically for motor action—see Bartlett, 1932; also see Schmidt, 1975, 1976). The operation of the model is based on activation and selection of schemas and uses a triggering mechanism that requires that appropriate conditions be satisfied for the operation of a schema. This model of schema activation is consistent with the literature on memory and models of schemalike computational mechanisms, as well as with the literature on the heterarchical nature of the motor control system (Szentagothai & Arbib, 1975).

The ATS model is novel only in its combination of previously stated ideas; all the components of the model have been stated elsewhere, although not in this combination and not for this purpose. Thus, the notion of schemas is well established in the study of perception and memory and somewhat so in the study of motor skills. The notion of activation values among schemas has been discussed for the related concepts of semantic networks by Collins and Loftus (1975) and for memory knowledge structures by Anderson (1976). The importance of trigger conditions is widely recognized in the literature on computational systems, the development most pertinent to this model being the production system (Newell, 1973; Waterman & Hayes-Roth, 1978). The formulation used here was partially developed by Rosenbloom (Note 1) and has been elaborated by Norman and Shallice (Note 2). The ATS framework is being explored for perceptual processing (McClelland & Rumelhart, Note 3; Rumelhart & McClelland, Note 4) and for the control of motor sequences in typing (Rumelhart & Norman, Note 5).

The novelty of the current model lies in several of its aspects: first, the combination of schemas, activation values, and triggering conditions; second, the application of motor action sequences; third, the role of intention; fourth, the consideration of the operation of cognitive systems when several different action sequences are operative simultaneously; and fifth, the specific application of this framework to the classification of slips. In

order to analyze most slips, the model need only be specified in its general principles of operation. More detailed specification is, of course, required for the understanding of any specific action sequence, but at the moment there are not sufficient data to justify more details. Fortunately, a general analysis suffices for the analysis of most slips.

Intention, Parent and Child Schemas

For the current analysis, details of the structure of schemas are not necessary. It suffices to view a schema as an organized body of knowledge, including procedural knowledge that can direct the flow of control of motor activity. Each schema is assumed to cover only a limited range of knowledge or actions. As a result, any given action sequence must be specified by a rather large ensemble of schemas, organized in a hierarchical control structure. One schema may need to invoke other schemas, passing to them particular values that the variables of the schemas must assume for the particular actions to be performed. Information passes both down from the higher-order schemas to the lower ones and also back up from lower-order schemas to higher ones.

For now, what is important is that a given action sequence has a number of different schemas that control the various aspects of the action. The highest-level schema is called the *parent* schema, with the subschemas that are initiated by the parent schema for the control of component parts of the action sequence being called *child* schemas. Each child schema may act as a parent schema to further child schemas. The concept of intention is equated with the initial, highest-level parent schema.

A major assumption of the ATS theory for slips is that skilled actions—actions whose components are themselves all highly skilled—need only be specified at the highest levels of their memory representations. Once the highest-level schema is activated, the lower-level parent components of that action sequence complete the action, to a large extent autonomously, without further need for intervention except at critical choice points. (This argument is developed in more detail by Norman & Shallice, Note 2.)

A major justification for the use of acti-

vation values comes from consideration of the forms of interactions that are required of schemas in such domains as perception and action. In these domains, activation values offer a mechanism for considerable interaction among schemas, allowing a schema to constrain and support any others that share common data bases or require similar resources. These issues are addressed in the papers by McClelland and Rumelhart (Note 3), Rumelhart and McClelland (Note 4), and Rumelhart and Norman (Note 5).

Note that numerous schemas will be activated at any given time. This implication results from two factors. First, any given action sequence is usually quite complex, involving a large number of component schemas. Second, because many (most) action sequences may require considerable time to be completed (consider the act of eating dinner or of walking to a restaurant), multiple intentions and schemas are usually active at any one time. The determination of the appropriate triggering conditions for a given schema then becomes a critical factor in the correct performance of an act. Activation values do not provide a sufficient mechanism for determining the appropriate temporal ordering of sequences. The model provides each schema with a set of specific conditions that are required for it to be triggered. An activated schema can be triggered by current processing activity whenever the situation matches its conditions sufficiently well. Exact match is not required—otherwise it would not be possible to account for many of the observed slips—but we assume there is a trade-off between level of activation and the goodness-of-match to the trigger conditions. The mechanism that is being considered here is that of “descriptions” (Norman & Bobrow, 1979). There are a number of different possible theoretical specifications of schemas, but for current purposes it is only important that there is selectivity of activation and triggering.

Consider an example. When I drive home from the University, the intention to go home activates a host of relevant child schemas. These schemas then get triggered at appropriate times by satisfaction of their conditions by previous actions, by the environment, or by perceptions. I need not con-

sider the details: I intend only that I should drive home. I can now do other tasks such as talk to a passenger, listen to the radio, and think about things other than the driving. The normal schemas required for avoiding obstacles, maintaining speed, braking properly, and following the correct route all have been activated and all trigger themselves when appropriate conditions arise. Conscious attention to the task can vary, with the task itself demanding attention at critical action points. Suppose, however, that I wish to drive to the fish store, not to my home. Because the fish store route is almost identical to the route required to go home, it is specified as a deviation from the better-learned, more frequently used home route schema. For this purpose I must set up a new schema, one that is to be triggered at a critical location along the usual path. If the relevant schema for the deviation is not in a sufficiently active state at the critical time for its triggering, it is apt to be missed, and as a result, the more common home route followed: I find myself home, fishless.

What I have given is a preliminary, high-level statement of a theory of act selection. Although the details are not presented, the specification is sufficient for current purposes. The essential assumptions are that any given action sequence is controlled by an ensemble of child schemas, that at any one time numerous schemas for a number of different sequences may be active. Schemas only invoke actions when they have been triggered, and this requires satisfaction of trigger conditions plus a sufficiently high level of activation.

Application of the Theory of Action to the Interpretation of Slips

In this article, I concentrate on action errors. Verbal errors are analyzed when they exhibit semantic properties or some interaction with planning or motor operations.¹ In addition, I use the examples of motor slips from the work of Reason (1975, 1976, 1977, 1979). Some examples come from the book by Hurst (1976) and from official government accident reports. I have also used the collection of pilot errors by Fitts and Jones (1961a, 1961b), although a number of these

errors are not relevant to the analyses that I am performing. In total, I have examined roughly 1,000 incidents, 200 of which were from my own collection.

The theory of action permits numerous opportunities for slips. There can be error in the selection of the intention or errors in the specification of the components. Even if the appropriate schemas are all activated, there can be errors of performance when schemas are triggered out of order or when a relevant schema is missed. There can also be errors resulting from the intrusion of unwanted activities from thoughts, from the occurrence of some event in the world that triggers an unintended response, or from a well-learned, familiar habit's taking control of action.

The basic classification of slips has three major headings, each corresponding to a different aspect of act formation or performance, and each contributing a source of error. These three major sources of action slips are (a) the formation of the intention, (b) activation, and (c) triggering. The complete classification is given in Table 1.

Slips During the Formation of an Intention

The formation of an intention is the result of many considerations, including the overall goals of the person, decision analyses, problem solving activities, situational analyses, and so on. Any or all of these can be faulty, but most are not within the focus of this article. Here I start with intentions as given and therefore ignore errors that result from the decision-making or problem-solving aspect of intention formation. However, there are still two classes of intentional problems that do lead to relevant action slips: errors in classifying the situation and errors that result from ambiguous or incompletely specified intentions.

¹ I only analyzed slips that had been recorded immediately after the incident by either the perpetrator or an observer. I attempted to get as complete a record as possible, including what the person had been thinking and how the slip was discovered. Some of the other sources of slips were not collected in this way (e.g., those of Fitts & Jones). For the purposes of mapping slips to the theory, a precise determination of the occurrence is required.

Table 1
A Classification of Slips Based on Their Presumed Sources

Slips that result from errors in the formation of the intention
Errors that are not classified as slips: errors in the determination of goals, in decision making and problem solving, and other related aspects of the determination of an intention
Mode errors: erroneous classification of the situation
Description errors: ambiguous or incomplete specification of the intention
Slips that result from faulty activation of schemas
Unintentional activation: when schemas not part of a current action sequence become activated for extraneous reasons, then become triggered and lead to slips
Capture errors: when a sequence being performed is similar to another more frequent or better learned sequence, the latter may capture control
Data-driven activation: external events cause activation of schemas
Associative activation: currently active schemas activate others with which they are associated
Loss of activation: when schemas that have been activated lose activation, thereby losing effectiveness to control behavior
Forgetting an intention (but continuing with the action sequence)
Misordering the components of an action sequence
Skipping steps in an action sequence
Repeating steps in an action sequence
Slips that result from faulty triggering of active schemas
False triggering: a properly activated schema is triggered at an inappropriate time
Spoonerisms: reversal of event components
Blends: combinations of components from two competing schemas
Thoughts leading to actions: triggering of schemas meant only to be thought, not to govern action
Premature triggering
Failure to trigger: when an active schema never gets invoked because
The action was preempted by competing schemas
There was insufficient activation, either as a result of forgetting or because the initial level was too low
There was a failure of the trigger condition to match, either because the triggering conditions were badly specified or the match between occurring conditions and the required conditions was never sufficiently close

Mode Errors: Erroneous Classification of the Situation

When a situation is falsely classified, then the resulting action may be one that was intended and appropriate for the analysis of the situation but inappropriate for the actual situation. There are a number of possible reasons for the misclassification, but the one of most theoretical interest for the purpose of this paper is a *mode error*.

The name results from experience with computerized text editors that have explicit modes for entering text (text mode) and for giving commands (command mode). Failure to identify which mode the system is in leads to (frequent) errors of attempting to insert new text while the system is in command mode or to specify commands while it is in text mode. These errors can have serious

effects: In one experimental text editor, attempting to insert the word *edit* into a manuscript while the system is actually in command mode leads to destroying the entire manuscript and then destroying the ability to invoke the normal "undoing" of such widespread damage. Similarly, many devices have visual displays or buttons whose meaning depends on the mode the system is in (e.g., aircraft automatic pilots, digital wrist-watches). Failure to identify the mode correctly leads to erroneous interpretation of the display or erroneous action. In all these cases, the intentions, the act specification, and the carrying out of the acts are done properly; the fault lies in specification of the situation.

The most numerous examples of mode errors in my collection come from the use of computers. There are numerous instances

of people typing the "end-of-text" symbol required by the text editor to signify the completion of the text when they were actually using other systems that did not require the symbol or attempting to delete a file by using the editor command that deletes a line of text.

In other situations, one person reported attempting to move the carriage on his typewriter by hand while using a typewriter that did not have a movable carriage. Reason (1979) tells of a person who reported: "I sat down to do some work and before starting to write I put my hand up to my face to take my glasses off, but my fingers snapped together rather abruptly because I hadn't been wearing them in the first place." Reason also tells of a person who reported: "My office phone rang. I picked up the receiver and bellowed 'Come in' at it." From my collection there is the person who had been dictating for an hour with a hand-held microphone. He left the room to ask a question, then returned to complete the dictation. He picked up the telephone handset instead of the microphone.

As is usual, these errors most likely have several causes. But they share the characteristic that an action entirely appropriate for a situation is being performed, except that this is not the current situation. Errors of partial specification (description errors) seem also to be involved in the last two examples. The episodes of the bellowed "Come in" and the removal of the nonexistent eyeglasses could also be caused by capture errors.

Description Errors: Insufficient Specificity

Some slips of selection occur either when all the relevant information needed to form the appropriate intention is not available or when an appropriate intention has been formulated, but the description of the desired act is insufficient. This latter situation gives rise to what has earlier been called an incomplete description (Norman & Bobrow, 1979), leading to ambiguity in the selection of information from memory. These ambiguities can lead to such performance slips as the replacing of the lid to the sugar container on the coffee cup (they are similarly

shaped containers) or throwing a soiled shirt into the toilet rather than the laundry basket (again, they are similarly shaped containers: the laundry basket was in a different room from the toilet). Verbal slips frequently involve the substitution of one word of a related semantic field, such as *door* for *window* or *trampoline* for *hammock*. Table 2 presents some of the motor and verbal errors of specification in my collection.

It is obvious that a number of the slips in Table 2 have alternative categorizations. Saying "You need a pencil to turn that slot" instead of "You need a coin . . ." could result from several causes. The resulting behavior, however, is a substitution of one word for another.

The ATS framework provides the mechanisms that allow these classes of errors to occur. However, the theory does not address the issue of why the particular word *pencil* might have been substituted for *coin*. Here, it is quite possible that further knowledge of situational factors, or knowledge of the thoughts active at the time, or a clinical analysis of the person would demonstrate the existence of contributing factors that, working through the mechanisms of the ATS formalism, gave rise to this particular slip at this particular time. Unfortunately, in most of the situations analyzed here, there is insufficient information to determine these other factors.

Slips That Result From Faulty Activation of Schemas

The activation of a schema can be faulty in one of two ways: A schema may be unintentionally activated, thereby causing an action to intrude where it is not expected; or a schema may lose its activation before its appropriate time to control behavior has occurred, thereby leading to omission of its components of the action sequence.

Unintentional Activation

Unintended activation of a schema can occur for several reasons, including the reasons discussed in the section on errors in the formation of the intention. More interesting, however, are errors that result from capture, by data-driven activations or by associations.

Table 2
Slips of Selection: Description Errors or Errors in Specificity of Description

Situation and intention	Action (or speech)
Eating bread. A's piece on plate, B's piece on counter (several feet apart). B intends to eat B's piece.	B picks up A's bread, bites into it, says "Oh my goodness, I'm eating yours."
Put toothbrush away in glass on counter.	Put toothbrush in hairbrush location: in cabinet, under counter, on opposite side.
Put lid on sugar bowl.	Put lid on coffee cup (same size opening).
Toss soiled T-shirt into laundry basket.	Toss shirt into toilet (different room than laundry basket).
Glass and coffee cup side by side (both empty). Intend to pour orange juice into glass.	Pour orange juice into cup. Notice only when later attempting to pour coffee into cup.
Intend to take rice from storage jar and measure in measuring cup.	Pour cooking oil into measuring cup: (both oil and rice kept in glass containers on counter top).
Turn on automobile engine. Intend to shift into gear.	Put on lights. (It was daytime.)
Intend to step on motorcycle brake (by depressing pedal with right foot).	Push gearshift lever (left foot).
Type a tab (large bar at top of keyboard).	Type space (large bar at bottom of keyboard).
Stop car. Intend to unbuckle seatbelt.	Stop car. Unbuckle watchband.
Push button to turn off exposure meter of camera.	Push shutter button (take picture).
Intend to say, "You need a coin to turn that slot."	"You need a pencil to turn that slot."
Intend to say, "The only language they had in common was Russian."	"The only language they had in common was English." (Observation recorded in Moscow.)
Intend to say, "I am a sheep in wolf's clothing."	"I am a sheep in lamb's clothing." (Said correctly 40 minutes previously.)
Intend to say, "Speech is very much overspecified."	Speech is very much oversimplified."
Intend to say, "New flight started to Amsterdam."	"New flight started to Chicago."

Capture slips. A capture error occurs when a familiar habit substitutes itself for the intended action sequence. The basic notion is simple: Pass too near a well-formed habit and it will capture your behavior. This set of errors can be described by concepts from the traditional psychological literature on learning—strong habits are easily provoked. The traditional mechanism is stimulus generalization. In current terms, if the habit is strong enough, even partial matches from the situation are apt to activate the relevant parent schema, and once activated, it can get triggered.

A capture error is a form of error of activation, closely related to errors caused by thoughts or by external activation. Still capture errors have a certain flavor about them that set them off. Reason (1979) described them in this way:

Like the Siren's call, some motor programs possess the power to lure us into unwitting action, particularly when the central processor is occupied with some parallel

mental activity. This power to divert action from some intention seems to be derived in part from how often and how recently the motor program is activated. The more frequently (and recently) a particular sequence of movements is set in train and achieves its desired outcome, the more likely it is to occur uninvited as a "slip of action."

The classic example of a capture error has already been mentioned: the example from James of the person who went to his room to change for dinner and found himself in bed. Here are two more examples, one from my collection and one from Reason's:

I was using a copying machine, and I was counting the pages. I found myself counting "1, 2, 3, 4, 5, 6, 7, 8, 9, 10, Jack, Queen, King." (I have been playing cards recently.)

I meant to get my car out, but as I passed through the back porch on my way to the garage I stopped to put on my Wellington boots and gardening jacket as if to work in the garden. (Reason, 1979).

External activation (data driven). In the class of slips called "data driven," the intrusions result from the analysis of external

events: The environment forces an intrusion. This class is similar to the other forms of activation error, with the distinguishing feature being that there is some obvious environmental cause for the act. The most prominent example is the Stroop phenomenon, a classic demonstration experiment in psychology in which the names of colors (e.g., *blue*) are printed in colors that differ from the name (so that the word *blue* might be printed with red ink). The task is to look at the word as rapidly as possible and say aloud the name of the ink color in which it is printed. There is extreme difficulty caused by the intrusion of the printed names. Here are some other examples of data-driven slips:

I had just given away my last cigarette. A smoker never lives with the knowledge that he does not have cigarettes available. At that time I did not have enough change to buy a pack from the vending machine. I went to my friend's room in the dormitories and got the exact amount needed to buy a pack of cigarettes. I went directly to the vending machines, put my money in and pressed the selection button. The pack was not delivered but the machine did not return my money. So I went to the laboratory to borrow some more money and headed back to the vending machines. I intended to try a different selection button, hoping the machine would work this time.

When I got to the vending machines, I put twenty cents in the *coffee machine*, when I realized that I was there to buy cigarettes, not coffee. Since the money was not recoverable, I got the coffee even if I did not really want it.

I then went back to the laboratory, got some more change, and headed back again to the vending machines, this time successfully. (The story has been shortened from the original.)

B was assigning a visitor a room to use. Standing in front of the room, at the telephone in an outside alcove, B decided to call the department secretary to tell her the room number. Instead of her telephone number, B dialed the room number. (B knew the phone number well; for the past four years it was his phone number when B served as department chair.)

Associative activation. This class differs from capture activations in that there need not be any formal similarity between the action sequences involved, but simply a strong association between them. Thus, the intention activates a relevant set of schemas that, by association to other schemas in memory, cause those others to become activated. This is the mechanism of "being reminded of." However, once the reminded-of

schemas are activated, it may be they that control the resulting actions rather than the intended schemas.

Errors of associative activation seem to occur most frequently in speech. One example occurred during discussion of the difficulty of viewing the stars from the La Jolla/Del Mar area (because the nights are often foggy or cloudy): "You want to see stars? Go to Lick Observatory (Pause) Why did I say that? I was thinking Palomar. I was even visualizing Palomar." (The speaker had lived for several years at Stanford, where the Lick Observatory is located, hence the strong association of "Lick" to the concept of "observatory.")

Similar examples are easy to find, such as the following conversation: "She stopped off in Cambridge, England. She used to live in Cambridge, Boston. Cambridge, umm, Massachusetts." Or the comment by a person while driving along the street of a town looking for a place to eat, as the car passed El Nopalito (a Mexican restaurant): "They have Chinese—Japa—Mexican food to go."

Loss of Activation

When the appropriate schemas for an action schema are activated, some may lose activation as a result of the normal decay and interference properties of primary memory. The result shows up in several different ways, depending upon the exact schema that was lost and when in the temporal events of the action the schema was lost.

One result can be that of losing the desired intention but allowing the behavioral repertoire to continue to its next logical junction. This led one of my informants to stand staring into the refrigerator wondering why he was there. Here is another, more complete example:

I have to go to the bedroom before I start working (writing) in the dining room. I start going there and realize as I am walking that I have no idea why I go there. Knowing myself, I keep going, hoping that something in the bedroom would remind me. . . . I get there but still cannot recall what I wanted. . . . so I go back to the dining room. There I realize that my glasses are dirty. With great relief I go back to the bedroom, get my handkerchief, and wipe my glasses clean.

Sometimes the components of an action

are misordered. Thus, a student reported the following incident:

I was at the end of a salad bar line, sprinkling raisins on my heaping salad, and reached into my left pocket to get a five-dollar bill. The raisins knocked a couple of croutons from the salad to the tray. I reached and picked them up, intending to pop them into my mouth. My hands came up with their respective loads simultaneously, and I rested the hand with the croutons on the tray and put the bill in my mouth, actually tasting it before I stopped myself.

Verbal misordering of components can follow similar patterns as in this report:

Once while jogging with a colleague early in the morning, I reported my academic history as "I got my degree at Harvard and was a post-doc and faculty member at Penn." (Exactly the reverse of the facts.)

Another class of errors is to leave out a step in a sequence, such as to forget to put the water in the coffee maker. Studies of aircraft accidents (Fitts & Jones, 1961a, 1961b) reveal that skipped steps are a frequent cause of accidents.

Yet another obvious class of error would be the repetition of a step in a sequence or the restarting of a sequence at some earlier stage. I have observed people (and myself) engaging the starter of an automobile after the engine had already been started. (This could, of course, also be classified as a mode error.) No incidents of this sort are in my collection, but Reason (1979) does provide a number of examples:

I started to pour a second kettle of boiling water into a teapot full of freshly made tea. I had no recollection of having just made it.

As I was leaving the bathroom this morning, it suddenly struck me that I couldn't remember whether or not I had shaved. I had to feel my chin to establish that I had.

I put a cigarette into my mouth, got my matches out, then instead of lighting the cigarette I took another one out of the packet.

Slips That Result From Faulty Triggering

A schema may be properly selected and activated but lead to a slip because it is triggered improperly, either at the wrong time or not at all. The most famous examples of inappropriate triggering that lead to reversals of event components are Spoonerisms, in which components of words are in-

terchanged, as in Spooner's example of "You have tasted the whole worm" instead of the intended "You have wasted the whole term."²

One form of error is to blend the components of actions. Presumably, these errors occur when two or more active schemas are triggered simultaneously, sometimes resulting in the merging of two schemas that are appropriate for the situation, sometimes merging a relevant schema with one that is not relevant (or, under the clinical interpretation, not desired). Blends sometimes result when a person is unsure which of two actions to perform: The result is a mixture of both, as when indecision between the choice of the words *close* and *shut* yields the response *clut*. Merges tend to involve activation and anticipation components, such as in the saying of "financed by the Rockebrothers, uh, the Rockefeller Brothers Foundation", or mixtures of related names, as when a speaker commented on "some interesting studies by Lynn Shepard." (The speaker did not notice the slip; Lynn Cooper has worked with Roger Shepard and has published numerous joint articles with him.)

A large class of errors occurs from false triggering of acts among the things currently active in mind. Thus, one can have an anticipation error such as "She presented these to American subjects and she presented these to Chinese—um, Japanese. I'll get to Chinese in a minute." Or, "Suppose you put a string around a ten-foot earth," where the intent was to say "ten-foot ball," but the speaker was simultaneously planning ahead how to talk about the problem of putting a string around the earth.

With a computer system, many errors come from doing the desired result rather than the action that leads to the result. Thus, because typing the "break" key terminates the program and leads to the appearance of the symbol % on the screen, several students have reported typing the % directly rather than the break key. (The % sign is never

² There is reasonable evidence that Spooner's reversals were often deliberate, carefully planned and thought out. Thus, this example stretches credulity. Nonetheless, the basic phenomenon is real and numerous examples are well documented (see Fromkin, 1973, 1980). For example, one of my colleagues said "Ruman and Normalhart" instead of "Norman and Rumelhart."

used as a command in this particular computer.) Additional examples of anticipation errors are the following:

I was typing a note to some students, stating when I could meet with them. I was mentally reviewing my day as I typed. I had a lunch appointment at 12:00 p.m., so I decided I could meet with them at 2:00 p.m. I typed "can we eat." I then realized the error and changed the "eat" to "meet."

One day as I was running on my morning trek, I saw a woman ahead. I was counting steps, but as I neared the woman I decided to say "Good morning." When I got to the woman, she smiled and said "Good morning," and I responded "Thirty-three."

A related class of errors comes from confusing thoughts with deeds. This is a lack of action rather than an intruded action, but the cause is related: An activation in primary memory was misused, in this case to substitute for the act.

I think of asking A to make more coffee and later complain of the lack. My thought, it turns out, was never voiced.

I make an error typing a line on the computer, think of typing the special character that deletes the line (@), and then continue typing, only to find that the computer responds with an error message. The @ sign was only thought, not actually typed.

Slips that result from failure to perform some action are more difficult to detect than errors that result from a falsely executed action. Indeed, if both the action components and the intention are forgotten, there is little to signal the error to either the person or an onlooker. Slips resulting from failure to do something are common in experience, however, such as forgetting to mail a letter or to stop at the bank on the way to work. Some of these cases are covered in the section on lack of activation.

The Detection of Slips

The Need for Feedback Mechanisms in Cognitive Behavior

Many slips are detected by the perpetrator, often as the act is being initiated and before any real headway has been made for the discrepant behavior. Sometimes slips go undetected for relatively long periods, and sometimes they are never detected. I presume that some slips are caught so early in their cycle that they are unseen by the ob-

server and are perhaps even unconscious in the producer.

In order for discrepant behavior to be detected, two things are necessary: a feedback mechanism with some monitoring function that compares what is expected with what has occurred; a discrepancy between expectations and occurrences. The task is non-trivial, for the specification of the intention is at a considerably different level than are the mechanics of the act.

The existence of feedback mechanisms seems a logical necessity in the control of human behavior (or almost any complex behavior, animal or machine). In cognitive psychology, feedback mechanisms have played almost no role, probably because the emphasis has been on the reception of information rather than the performance of acts (but see Miller, Galanter, & Pribram, 1960). Those areas of psychology that study output—manual control, human factors, and motor skills—do worry about feedback, but there has been little interaction with cognitive psychology.

Some Examples of Error Monitoring

Many, but not all, of the errors in my collection of slips were caught by the perpetrator. (Unfortunately, in most collections of slips, this information is not recorded. Even in my own collection, this information is not always available.) Slips are caught at various levels of action, from the start of the activity to after considerable delay. Table 3 presents examples of the catching (or failing to catch) of slips at different points in the act. Note that many of these slips are caught only with the active cooperation of the observer or the listener. And sometimes even the cooperative effort fails. With motor slips, at times the slip is discovered only because the incorrect action leads to a situation that reveals itself later. Thus, one subject reported pouring orange juice into the coffee mug, drinking the juice, and noticing the problem only when desiring to pour a cup of coffee; the remnants of the juice attracted her attention.

Note the critical point of the feedback analysis: For a slip to be detected, the monitoring mechanism must be made aware of the discrepancy between intention and act.

Table 3
Examples of Detecting Slips at Various Stages in the Action

Caught in the act

"I caught myself as I was about to pour the tea into the opened can of tomatoes that was just next to (left of) the teacup." (The can was empty.)

Caught just after the act

"One of the problems with the TV guide—*the TV guide*—the restaurant guide."
 "Financed by the Rockebrothers, uh, the Rockefeller Brothers Foundation."

Multiple corrections

"This is paid for by NSF, I mean CHIP, I mean Sloan."
 "I think it's time he cleaned up his office, too. Umm, desk; umm, room."
 "They have Chineec—Japa—Mexican food to go."

Not caught (by the perpetrator)

A: We're not very good at badminton anymore.

B: What?

A: Badminton.

B: Badminton?

A: Oh, I did say badminton, didn't I. Table tennis.

B: Where did that come from?

A: I was thinking about planning the yard, and thinking of putting in a badminton court.

"I told the water skiing story in which the skier is almost hit by another boat. I said, ' . . . almost hit by another car.' A listener interrupted to point out the error. I was skeptical, but another listener confirmed the error."

Caught after a very long delay

A noticed that B was using his special (and expensive) scissors with serrated blades to cut some loose threads from clothes. (Both A and B had agreed that the scissors were reserved for trimming hair.)

A: Hey—No! That's a hair comb.

B: Oh—sorry.

The normal activities then continued. There was no further conversation. B went and got another pair of scissors. About a minute or two after the conversation:

A: I meant that was a hair *scissors*, only to be used to cut hair.

B: I knew what you meant. I did have the vague feeling that something was wrong, but I wasn't sure what. Now I realize that you called the scissors a comb. I understood you though.

But if the monitoring function only has access to the act specification, it can only say how well the act is performed, not if it is the correct one. The following example demonstrates a form of error that was not detected by the speaker:

A was driving a van and noticed that the rearview mirror on the passenger side was not adjusted properly. A meant to say to the passenger on the right, "Please adjust the mirror," but instead said, "Please adjust the window." The passenger, B, was confused and asked, "What should I do? What do you want?" A repeated the request: "Adjust the window for me." The situation continued through several frustrating cycles of conversation and attempts by the passenger to understand just what adjustment should be made to the window. The error correction mechanism adopted by the driver was to repeat the erroneous sentence more and more loudly.

The apparent difficulty here is that the feedback monitoring was at the wrong level to detect the failure in the word selection.

Instead, it attempted to correct failure in word enunciation. Suppose that A's intention had been imprecisely specified as "Adjust that (ill-specified) object on the right side of the van," and suppose that this intention had spawned a set of schemas and action units that eventually chose "window" as the name of an object on the right side of the vehicle. This would lead to a failure to detect the error, for whatever mechanism monitors the speaking of the word would be checking to see that the erroneous word, *window*, was pronounced properly. (The error itself is possibly also a form of data-driven slip, for the window was in the visual path to the mirror, and the sight might have helped select the incorrect word. Whatever the cause, the point is that the error was made at a level undetectable by the monitoring function.)

Levels of Feedback Systems

In the terms used in this article, the basic control sequence is from intention to triggering to action. Note that the only way that an error can be detected is for it to occur within the action triggering mechanism or in the actual mechanics of performing the response. If the intention is incorrectly specified, the error cannot be noted—not by this system, anyway. There is much too large a difference in the level of specification of the intention and the actual acts that get done: The comparison mechanisms would have to be horrendously complex. Suppose a person is carrying out the intention to drive home. One of the actions performed along the way is to move the right hand down while simultaneously moving the left hand up. (The driver is rotating the steering wheel of the automobile in order to turn the car to the right.) Is this an appropriate set of actions for the intention? The difficulty is that the intention is specified at a very high level of abstractness (“drive home”), whereas the act is specified either in terms of muscle signals or limb movements. To compare intentions and actions, the two must be at the same level of specification.

Consider the problem of language behavior. The intention is specified at some abstract, “idea” level, but the output of the motor control system is the production of sound waves. To match how well the sound conveys the idea requires the monitoring function to go through the whole process of speech understanding, first to identify the words that have been spoken, then to determine if the interpretation of those words matches the intention.

The solution to this difficulty is for the action system to have many feedback comparison processes, each monitoring different levels of the operation of the system. In speech, at some low level, feedback processes probably monitor how well sound frequencies and intensities match the intended voice pitch and loudness. Other systems probably monitor rhythm and stress, intonation and pronunciation. A different system must compare the intended word selection with that actually being uttered (or triggered for ut-

terance), and another system monitors the meaning and affect. Different levels of feedback are required for different purposes.

With motor actions, similar division among levels is required. Each level of specification of the intention must be decomposed into more basic levels in order for an action to take place, each new decomposition more finely dividing the actions required and more precisely specifying what must be done. And each new level of specification is, in turn, decomposed into its basic components, until some primitive level of act specification is reached. Feedback and monitoring is required at each level.

Comments on Naturalistic Errors

The collection and analysis of naturally occurring errors forces us to consider behavior that is not constrained by the limitations and artificiality of the experimental laboratory. By examining errors, we are forced to demonstrate that our theoretical ideas can have some relevance to real behavior. There are situations that are simply too complex to be reproduced in the laboratory; for example, naturalistic observations are the only way to obtain data of people under extreme stress (in some cases, while they face severe injury or death during an emergency situation).

But naturalistic observations have disadvantages. It is difficult—sometimes impossible—to record exactly what went on. Observers are not always around, and even when they are, they are not always ready to make the detailed observations that would be required. Records from memory (and even from direct perception) are notoriously unreliable.

One common question about these errors concerns their frequency of occurrence, both with respect to each other (relative frequency) and in absolute terms (absolute frequency). Naturalistic observations cannot be used to determine these numbers. I have not provided percentages for my observations, because I believe that the numbers would be misleading. Observers are selective in what they record. It is sometimes difficult to determine what should count as an error. The

records are incomplete, for the goal was to collect a general sampling of all forms of errors, and exhaustive recording was not used. If the goal is to determine relative frequency, then only a complete record will do. Accurate sampling and statistics probably require video recording of large segments of behavior and then careful perusal of the tapes in order to transcribe in detail the situations identified as errors (see Deese, 1978). Mackay (1973, 1980) has argued that naturalistic data can be used to give reasonable statistical estimates when "a strong case can be made that the missing data are random or unselected with regard to what you're analyzing" (Mackay, Note 6).

To validate what has been theoretically postulated as the cause of errors, laboratory tests are useful. It should be possible to cause many of the errors in the classification scheme to occur within the experimental laboratory. Errors of activation and of capture seem especially likely to be reproducible. MacKay, Baars, and Motley have been quite successful in generating verbal errors in laboratory situations (Baars 1980; Baars & MacKay, 1978; Baars & Motley, 1976; Baars, Motley, & MacKay, 1975; MacKay, 1973; MacKay & Soderberg, 1971; Motley & Baars, 1976). I believe their techniques and others can be adapted to the study of motor behavior.

Summary

In this article I have attempted to draw from a reasonably large collection of slips sufficient components and constraints for a theory of action. I propose that a system of activated schemas with a triggering mechanism for determining appropriate time for activation provides a satisfactory framework for the categorization and analysis of slips. To perform a well-learned action sequence, only the highest-level parent schema must be specified: This corresponds to the intention. This schema will, in turn, activate whatever child schemas are required to guide the various components of the action sequence. Each activated component is a sensorimotor schema, with conditions that specify when it is to be triggered into action. Were this all there were to the theory, the

only errors that could occur would be errors of ordering in which a relevant component missed its triggering situation, or an erroneous one was mistriggered when the existing situation provided a sufficient match for its trigger conditions.

However, the theory allows for multiple sources of activations, for example from the external world (data-driven activation), from internal processing (thoughts, associations, prior or future action components), or by capture by well-learned familiar habits. The likelihood that a given schema will be triggered is a joint function of its level of activation and of the match between the goodness with which the current conditions match the triggering conditions. This trade-off provides an obvious place to develop experimental tests of the theory. Slips occur for only three reasons: the formation of the intention is in error; there is faulty activation of schemas; there is a failure in satisfying the conditions for triggering.

Feedback plays an essential role in complex behavior. With slips, it is of interest to discover under what conditions a slip can be discovered and when it cannot. The monitoring of actions is a basic component of a feedback control system, but the monitoring function requires that the comparison of intention and action be done at the same level of specification. Because complex acts have many differing levels of specification, each with its own relevant schemas and operations, the monitoring function must also be performed at many different levels. The performance of an action, from initial conceptualization through realization, is then the process of decomposing the original intention into a sequence of physically performable acts, with multiple levels of feedback analysis accompanying the acts.

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