Information Reduction During Skill Acquisition: The Influence of Task Instruction

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H. Haider and P. A. Frensch's (1996) information reduction hypothesis holds that with practice, people learn to distinguish task-relevant from task-redundant information and to ignore task-irrelevant information. In 2 experiments, the authors examined whether degree of information reduction can be directly affected by task instruction. Participants verified alphabetic arithmetic tasks containing task-relevant and task-irrelevant information. Participants were asked to optimize their accuracy or their speed of performance throughout the entire experiment or to optimize accuracy for half of the experiment and speed for the other half of the experiment or vice versa (first speed, then accuracy). In addition, time duration of stimulus presentation under speed instruction was systematically reduced over practice in Experiment 2. Results showed that amount of information reduction was affected by instructions, suggesting that the process of information reduction is at least partially under voluntary control.

Think of two people, one an experienced user of computer software and the other an inexperienced user, both trying to install some new computer software. During the installation process, a number of messages are displayed on the screen, some of which need to be attended to and some of which may be safely ignored. Whereas the inexperienced user is likely to thoroughly read through all messages displayed on the screen, the skilled user very likely pays attention only to those messages that require him or her to respond and more or less ignores all other messages. Consequently, the skilled user needs less time to install the new software than does the unskilled user.

What this example suggests is that the transition from unskilled to skilled task performance can be partly characterized in terms of an increasing ability to sort out task-relevant from task-irrelevant information. In general, skilled performers are likely to know which of the given task-information is relevant and which is irrelevant and are therefore able to focus their processing on task-relevant information. Unskilled performers, in contrast, do not possess the knowledge that would let them distinguish between task-relevant and task-irrelevant information. One aspect of acquiring a skill, then, appears to be the ability to limit task processing to task-relevant information, an ability that we refer to as information reduction (Haider & Frensch, 1996).

Surprisingly, this aspect of a skill has received little attention in most current theories of skill acquisition (e.g., Anderson, 1983, 1987, 1992; Lassaline & Logan, 1993; Logan, 1988; Logan & Etherton, 1994; but see, Anderson, Matessa, &
According to most theories, practice-related improvements in the performance of a skill (e.g., increasing speed and efficiency; decreasing effort) are due to (a) qualitative changes in the task processing (e.g., Cheng, 1985; Logan, 1988), (b) an increasing efficiency to perform individual task components (e.g., Anderson, 1982, 1987, 1992), (c) increases in the efficiency to perform sequences of task components (e.g., Anderson, 1982, 1987; Frensch, 1991, 1994; Newell & Rosenbloom, 1981), or (d) some combination of these factors (e.g., Anderson, 1987; Frensch & Geary, 1993). In general, existing theories view performance changes that occur with increasing level of skill as being a result of an increased efficiency of information processing. In addition, the learning mechanisms underlying skill acquisition are typically seen as mechanistic and entirely data-driven (e.g., Anderson, 1987; Logan, 1988; Newell & Rosenbloom, 1981).

The neglect of information reduction in theories of skill acquisition is even more surprising if one considers that in a great number of everyday situations, such as driving or using modern electronic information systems (e.g., Internet), information has to be processed efficiently. Also, the phenomenon of information reduction is commonly acknowledged in many different areas of psychology (e.g., Christensen et al., 1981; Fisher & Tanner, 1992; Holding, 1985; Lambert, Spencer, & Mohindra, 1987; Myles-Worsley, Johnston, & Simons, 1988; Shapiro & Raymond, 1989; Strayer & Kramer, 1994a, 1994b). The phenomenon has been discussed theoretically for the domains of visual perception (e.g., E. J. Gibson, 1963; J. J. Gibson & Gibson, 1955; Kaptein, Theeuwes, & Van der Heijden, 1995; Van der Heijden, 1992), sports and perceptual motor skills (e.g., Abernethy, 1993; Helsen & Pauwels, 1993; Petakis, 1993), educational psychology (e.g., Bransford, Sherwood, Vye, & Rieser, 1986), and expertise (e.g., Ericsson & Lehmann, 1996; Shanteau, 1992; Shapiro & Raymond, 1989; Vickers, 1988). For example, Helsen and Pauwels (1993) analyzed the eye movements of experts and novices in tactical soccer situations and found that experts differed from nonexperts in the selectivity of information. Similarly, Shapiro and Raymond (1989) were able to show that novices’ performance could be improved when novices were trained to attend to task-relevant information only and to ignore task-irrelevant information. Taken together, these observations suggest the acquisition of an internalized evaluation function that helps to distinguish between task-relevant and task-redundant information and to base task processing on the relevant aspects of a task. Thus, an important question in skill acquisition is how people learn to selectively use information with increasing practice.

We have recently formulated a theoretical account of how information reduction might proceed when a cognitive skill is acquired (Haider & Frensch, 1996). Our theoretical view relates to findings we obtained with the alphabetic arithmetic task (AAT). In the AAT, participants are asked to verify alphabetic letter strings, that is, to judge whether a presented string follows the alphabet or not. Strings consist of an initial letter-digit-letter triplet, and a varying number of additional letters (e.g., D [4] I, E [4] J K L, D [4] J K, and E [4] J K L), and are either correct (i.e., they follow the alphabet; D [4] I) or incorrect (i.e., they do not follow the alphabet; D [4] J).

Because errors in incorrect strings always occur at String Position 3 (i.e., the letter to the right of the digit), the letters in String Positions 4 and higher are always correct and are therefore irrelevant for the verification task.

For our initial set of experiments with the AAT, we reported two main results (cf. Haider & Frensch, 1996). First, the effect of string length on verification times for correct strings (i.e., increased verification times for longer strings) declined significantly with task practice and
disappeared altogether after approximately 500 trials, indicating that the task-irrelevant information was no longer processed. Second, the magnitude of the string-length effect was unaffected by sudden and unexpected changes in the stimulus material. We interpreted these results in terms of a two-stage information reduction process: During the first phase, task-relevant and task-irrelevant information are distinguished, and during the second stage, task-relevant information is actively selected for processing (e.g., Allport, 1987; Neumann, 1990), and task-irrelevant information is actively ignored (e.g., Neisser & Becklen, 1975). In general, the two-stage view is consistent with arguments that have been made in other psychological contexts (e.g., J. J. Gibson & Gibson, 1955; Neisser, 1976; Trabasso & Bower, 1968).

We further theorized that the ability to distinguish between relevant and irrelevant information results from implicit (bottom-up) and/or explicit (top-down) learning mechanisms. In contrast, the active selection of relevant information and the ignoring of irrelevant information is the result of a voluntary strategic decision to no longer attend to the redundant information (Haider & Frensch, 1999).

Purpose of the Present Experiments

The assumption that limiting task-processing to the task-relevant information is under strategic control has important practical implications. If information reduction is indeed at least partially the result of a voluntary decision, then one should be able to externally influence the degree to which information reduction mechanisms are used. Insight in external facilitating and inhibiting conditions may eventually lead to the capacity to accelerate information reduction when this is wanted (e.g., implementing software by an experienced user) or decelerate it when it needs to be prevented (e.g., airline pilots’ preparations for a flight).

The primary purpose of the present studies was to experimentally explore whether degree of information reduction can be manipulated externally. One possible, and relatively straightforward, way to do just that is to instruct participants to optimize either their speed or accuracy of performance. We hypothesized that manipulating task instructions in this manner may have at least three different consequences. First, in accordance with a large literature on speed-accuracy trade-offs (Pachella, 1974; Pachella & Pew, 1968; Rabitt, 1989; Sperling & Dosher, 1986; Wickelgren, 1977), participants under speed stress should demonstrate faster latencies and higher error rates than participants under accuracy stress. Second, and more important in the present context, we expected that participants under speed stress would terminate processing of task-irrelevant information earlier during practice than participants under accuracy stress. Third, because information reduction is assumed to be under a participant’s voluntary control, instruction should affect degree of information reduction, irrespective of whether speed or accuracy instructions are given at the beginning or during training.

In relation to the first hypothesized outcome, it is well known in the response-time literature that participants can adjust their speed and accuracy of responding as a function of task instruction. The preferred explanation is that participants adopt different response criteria for different instructions: a conservative one under accuracy stress and a liberal one under speed stress (Pachella, 1974; Pachella & Pew, 1968; Rabitt, 1989; Sperling & Dosher, 1986; Wickelgren, 1977). Frequently, random walk models are used to capture the effects of setting response criteria on latencies and accuracy (e.g., Ratcliff, 1981, 1985; Treisman & Williams, 1984). In these models, it is assumed that setting response criteria affects both the speed of processing task information and the amount of information—extracted from a stimulus—that is necessary to trigger a response. If the response criterion is moved closer to the starting point (i.e., where the accumulation of information begins), then the amount of information that is needed to trigger a response is reduced. If the criterion is moved farther away from the starting point, then the amount of information necessary to trigger a response is increased.

In the language of random walk models, participants instructed to optimize speed of processing are likely to adopt a liberal response criterion, meaning that these participants will increase their speed of task processing and/or will strategically move their response boundaries closer to the starting point. In contrast, participants instructed
to optimize accuracy of performance are more likely to adopt a conservative response criterion, meaning that these participants will strategically move their response boundaries farther away from the starting point or will process task information more slowly.

With regard to the second hypothesized outcome, the setting of a response criterion needs, in principal, to be distinguished from the decision of which stimulus information the response criterion is applied to. Thus, for example, a participant may decide to use a liberal response criterion on information selected randomly from the stimulus. Or, alternatively, the participant may use a liberal response criterion on information that is extracted systematically, for example from left to right, if the stimulus is a written word.

The empirical question of how the manipulation of task instruction affects degree of information reduction relates to the question of which task information a selected response criterion is applied to. On the one hand, one possibility is to consider the setting of a response criterion as independent of the decision of which task information is processed. Deciding to respond quickly is, after all, a different decision than deciding to process only parts of the presented task information. According to the independence view, the possible prediction that speed stress will lead participants to ignore task-irrelevant information more than accuracy stress is not an automatic consequence of the prediction that speed stress will lead participants to respond more quickly than accuracy stress. It would indeed be a distinct possibility for participants under speed stress to process the entire task information very quickly but nevertheless decide not to ignore parts of the information. Conversely, participants under accuracy stress may adopt a conservative response criterion, that is, process task information very slowly and yet decide to no longer process task-irrelevant information.

On the other hand, however, a rational view suggests that the setting of a liberal response criterion may be accompanied by limiting task processing to task-relevant information. Thus, under speed instruction, participants may decide on the basis of little evidence to ignore task-redundant information in order to quicken task processing. In contrast, the setting of a conservative response criterion makes most sense if all available task information is processed. On the basis of this rational view, we predicted that participants who are instructed to optimize their speed of task processing should very quickly—on the basis of high uncertainty—decide to process task-relevant information only, resulting in a high rate of information reduction. Participants who are instructed to stress accuracy should ignore task-irrelevant information only if they are absolutely certain that the information is truly irrelevant, resulting in a much smaller degree of information reduction.\(^1\)

It is important to point out that methodologically, the effects of task instruction on the setting of a response criterion and on deciding which information is processed (i.e., information reduction) are difficult to separate, at least if the preferred measure of information reduction is latency-based, as is true in the present experiments. Indeed, a decreasing string-length effect—which is taken as evidence for information reduction in the present experiments—is an unavoidable consequence of declining latencies. Thus, it is one of the challenges of the present article to demonstrate that the manipulation of task instruction has any effect on information reduction above and beyond its influence on overall latencies.

Concerning the third hypothesized outcome, the ability to change a response criterion during training, Strayer and Kramer (1994b) have shown that participants are unable to dynamically adjust their response criteria. However, as mentioned above, the information reduction hypothesis holds that participants first notice that the AAT tasks

\(^1\) Any difference in degree of information reduction between conditions is affected by the number of participants who notice that task-irrelevant information exists because the decision to consistently and systematically ignore parts of the presented information can only follow the detection of task-irrelevant information. In principle, empirically obtained differences on measures of information reduction could therefore reflect differences in noticing that task-irrelevant information exists rather than differences in information reduction per se. Because participants under speed stress may be at a disadvantage for detecting task-irrelevant information, differences in noticing should, at worst, reduce (and not increase) the here predicted higher degree of information reduction in the speed condition over the accuracy condition.
contain task-redundant information and then voluntarily decide to ignore this information. Consequently, if the manipulation of task instruction generally affects degree of information reduction and if task instruction primarily affects a participant’s voluntary decision and not the process of detecting task-redundant information, then amount of information reduction should depend on instruction, irrespective of when speed or accuracy instructions are given. Thus, we expected that the effects of task instruction would be independent of whether the instructions are given at the beginning of or during training.

Overview of Experiments

In the experiments described in this article, all participants performed the AAT. As alluded to above, the task requires participants to verify alphabetic strings by judging whether or not the presented strings are correct or incorrect. In both Experiments 1 and 2, participants in two pure instruction conditions were instructed to optimize either their accuracy or speed of performance throughout the entire experiment (accuracy condition and speed condition, respectively). In addition, one control condition and two mixed instruction conditions were realized. In the control condition, participants were asked to simultaneously optimize both the speed and accuracy of their performance. In the accuracy—speed condition, participants were initially instructed to optimize the accuracy of their performance and were then later given speed instructions; in the speed—accuracy condition, participants were initially instructed to optimize their speed of processing and then later their accuracy. Experiment 2 differed from Experiment 1 mainly in that the time duration of stimulus presentation under speed stress was systematically reduced with increasing practice. This was done in order to examine the effect of time pressure on information reduction. Time pressure is one characteristic of those real-life situations in which humans are required to make important decisions (e.g., flying an airplane, driving a car, or playing fast ball sports). Thus, time stress might force them to limit task-processing to task-relevant information.

Experiment 1

There were five experimental conditions in Experiment 1: speed, accuracy, speed—accuracy, accuracy—speed, and control. The control condition allowed us to examine whether speed and accuracy instructions have symmetrical yet opposite effects or whether the effects are highly asymmetrical. Asking participants to optimize both speed and accuracy was deemed a more appropriate control condition than leaving the optimization of speed and/or accuracy up to the individual participants.

In accordance with the main hypotheses outlined above, we expected the speed and accuracy instructions to affect overall error rate, overall latency, and degree of information reduction. First, participants in the accuracy condition should set a more conservative response criterion than participants in the speed condition and, consequently, should respond more slowly and commit fewer errors than participants in the speed condition. Second, information reduction should be reduced under accuracy instructions relative to speed instructions. Thus, the string-length effect for correct strings—our measure of information reduction—should decline more rapidly for participants in the pure speed condition than for participants in the pure accuracy condition. In addition, if participants can flexibly adapt to changes in task instruction, then performance and degree of information reduction during the second half of practice in the speed—accuracy condition should differ significantly from performance (i.e., degree of information reduction) in the pure speed condition. Conversely, performance and degree of information reduction during the second half of practice in the accuracy—speed condition should differ from performance (i.e., degree of information reduction) in the pure accuracy condition.

Method

Participants

One hundred forty-one female and 54 male students at the University of Missouri at Columbia served as participants in the experiment. The participants ranged in age from 17 to 41 years ($M = 19.2$ years, $SD = 2.7$) and received course credit in an introductory psychology class for
their participation. Because of technical problems, data from 6 participants were lost.

**Materials**

A total of 30 correct and 30 incorrect alphabetic strings was used in the experiment. Correct strings consisted of an initial letter-digit-letter triplet (e.g., $E\{4\}J$) that began with one of 10 letters: D, E, F, G, H, I, J, K, L, or M. The 10 possible correct triplets were followed by zero, two, or four additional letters such that the entire string followed the alphabet. The digit in brackets was always 4. Thus, in all experimental conditions, there were $3 \times 10 = 30$ correct letter strings that varied in total length (three, five, or seven symbols). The construction of the incorrect letter strings was identical to the construction of the correct letter strings except that the letter immediately following the digit 4 was the letter that followed the correct one in the alphabet (e.g., $E\{4\}K$ instead of $E\{4\}J$).

Strings were presented at the center of a 9-in. (22.9-cm) diagonal video screen controlled by a Macintosh SE microcomputer. The letters were approximately 0.3 cm $\times$ 0.3 cm in size. Adjacent letters appeared approximately 0.2 cm apart on the screen. Participants responded by pressing either the “z” or the “3” key on the second row from the bottom of an extended Macintosh keyboard. Half of the participants were instructed to press the “z” to indicate that a string was correct and the “3” to indicate that the string was incorrect; for the other half, the key assignment was reversed.

**Procedure**

Participants were randomly assigned to one of the five experimental conditions (speed, accuracy, speed-accuracy, accuracy-speed, and control) and were tested individually in a moderately lit room. The experiment began with computerized instructions and a short practice session. Participants were told that their task was to verify alphabetic strings. They were informed about what constituted a correct string and were shown examples of correct and incorrect strings. Then, a short practice session followed in which participants evaluated five correct and five incorrect practice strings. In contrast to the experimental practice blocks, errors in the incorrect strings could occur both within and outside the triplet. Strings with errors outside the triplet were presented to ensure that participants would not ignore the irrelevant letters right from the beginning of the experimental phase. If participants made more than three errors on the practice strings, instructions and practice session were repeated.

When all participants had successfully completed the practice session, participants in the accuracy and accuracy-speed conditions were instructed to optimize their accuracy of performance, whereas participants in the speed and speed-accuracy conditions were instructed to optimize their speed. Participants in the control condition were instructed to optimize both speed and accuracy of performance. All participants were told to pay close attention to the entire string because errors could occur anywhere in the string. Thus, participants were not informed about the strings containing task-irrelevant information.

After they finished the fourth practice block, participants in the two mixed instruction conditions received new instructions. In the accuracy-speed condition, participants were told that from now on they should optimize their speed of responding. In the speed-accuracy condition, participants were told that from now on they should optimize their accuracy of responding.

Each trial began with the presentation of a fixation point at the center of the screen for 500 ms. The disappearance of the fixation point was immediately followed by the presentation of a string that remained on the screen until a response was made. The screen then went blank for 1,000 ms, after which the next fixation point appeared. The entire experiment lasted between 45 and 60 min, depending on experimental condition.

The experimental phase consisted of eight blocks of trials. Each block contained the 30 correct and 30 incorrect strings, such that all participants verified a total of 240 correct and 240 incorrect alphabetic strings (eight repetitions per string). The order of strings was randomly determined for each participant and each block. At the end of each block, participants received feedback. Under accuracy instructions, participants first received feedback concerning their error...
rates followed by feedback about their mean response times in the previous block. Under speed instruction, the feedback sequence was reversed.

**Design**

Dependent variables were participants' median verification times (reaction times) and their mean error rates per trial block. The only between-subjects variable was experimental condition (accuracy vs. speed vs. accuracy-speed vs. speed-accuracy vs. control). Within-subjects variables were practice block (one to eight), string length (three, five, seven), and string type (correct vs. incorrect).

**Results**

A first check ensured that only participants with reasonable error rates in the experimental phase were entered in the data analysis. To this end, mean error rates were computed for each participant and each trial block. Participants were excluded from all subsequent data analyses if their mean error rate was higher than 15% in each trial block (n = 5, n = 3, n = 15, n = 8, and n = 9, in the control, accuracy, speed, accuracy-speed, and speed-accuracy conditions, respectively). Participants with very high error rates were excluded from the data set because high error rates did not allow us to compute reliable individual regression slopes for the assessment of degree of information reduction in each trial block. At a group level, the results reported for the reduced sample did not differ qualitatively from those for the entire sample, however. The elimination of participants resulted in 16 remaining participants in the control condition, 42 remaining participants in the accuracy condition, 26 participants in the speed condition, 33 participants in the accuracy-speed condition, and 32 participants in the speed-accuracy condition. For all remaining participants, median response times (RTs) for correct responses were computed to correct and incorrect alphabetic strings separately for each block and each string length.

Manipulating task instructions bears the danger of generating speed-accuracy trade-offs that can make comparison of RTs and error rates across conditions difficult. In order to examine speed-accuracy trade-offs, the correlation between mean error rate and median RT was computed in each of the five experimental conditions, separately for Blocks 1–4 and Blocks 5–8. Results are shown in Table 1.

As can be seen in the table, reliable correlations between RT and error rate occurred only when participants were instructed to optimize speed. For Blocks 1–4, the correlation was negative and significant in the speed-accuracy condition and just failed to reach significance in the speed condition (p < .07). In Blocks 5–8, only the accuracy-speed condition showed a significant negative correlation; in the speed condition, the speed-accuracy trade-off disappeared with increasing practice. In general, a speed-accuracy trade-off occurred only in the speed conditions, not in the accuracy conditions. However, the correlations were all very small and do not qualify the findings reported below for RT latencies.

In all further analyses of Experiment 1 and Experiment 2, the adopted level of significance was α = .05. For significant effects, individual p values are not reported.

The discussion of the main results is divided into two sections. First, we discuss the effects of task instruction on overall mean error rates and RTs. Then, we turn to a comparison of the degree of information reduction in the five experimental conditions.

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<tr>
<th>Block and condition</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
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<td>Blocks 1–4</td>
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*p < .05.
Overall Error Rate and RT

Error rate. Figure 1 displays the mean percentage error rate in the five experimental conditions as a function of practice block. Because an initial analysis had not revealed any qualitative differences for correct and incorrect strings, individual error rates were averaged across the two string types. As can be seen in the figure, the mean error rate was higher in the pure speed condition than in the pure accuracy condition, indicating that the between-subjects instruction manipulation affected accuracy of performance. The control condition was in between the two but was somewhat closer to the pure accuracy condition, at least during the second half of the experimental phase.

A comparison of error rates for the mixed and the pure instruction conditions shows that participants were able, at least to some extent, to modify their performance when task instructions were changed. In the accuracy-speed condition, the error rate was initially indistinguishable from that in the pure accuracy condition but increased from 2% in Blocks 1–4 to 6% in Blocks 5–8. In contrast, in the speed–accuracy condition, the error rate was initially identical to that in the pure speed condition but decreased from 6% in Blocks 1–4 to 4% in Blocks 5–8.

In order to separately capture the effects of the initial setting and later changing of task instructions, we computed two Condition (control vs. accuracy vs. speed vs. accuracy–speed vs. speed–accuracy) X Practice Block mixed-design analyses of variances (ANOVAs) on participants’ error rates for the first (Blocks 1–4) and second (Blocks 4–8) half of practice. Block 4 was included in the second analysis in order to provide a baseline for the expected effects of changing task instructions.

The analysis for the first half of practice revealed significant main effects of condition, $F(4, 144) = 16.34$, $MSE = 35.36$, and of practice block, $F(3, 432) = 5.69$, $MSE = 17.83$, as well as a significant Condition X Practice Block interaction, $F(12, 432) = 2.60$, $MSE = 17.83$. A planned contrast confirmed the impression conveyed by Figure 1 that the difference between the two combined accuracy and the two combined speed conditions was significant, $F(1, 144) = 64.99$, $MSE = 35.36$. The speed and speed-accuracy conditions did not differ significantly from each other, nor did the accuracy and accuracy-speed conditions (both $p > .05$). In addition, the control condition differed significantly from the combined speed and speed–accuracy conditions, $F(1, 144) = 10.81$, $MSE = 35.36$, whereas the combined accuracy and accuracy–speed conditions just fell short of significance, $F(1, 144) = 3.14$, $MSE = 35.36$, $p < .08$.

The ANOVA for Blocks 4–8 revealed a significant main effect of condition, $F(4, 144) = 9.29$, $MSE = 63.89$, and a significant interaction between condition and practice block, $F(16, 576) = 4.79$, $MSE = 20.71$. As can be seen in Figure 1, the pattern of results was considerably noisier for the second half of practice, as compared with the first half. Whereas the error rates in the pure
instruction conditions remained at first-half level, the error rates in the mixed conditions changed in the expected direction and eventually reached the level of the pure conditions.

Separate planned follow-up contrasts comparing the speed–accuracy condition with the speed condition and the accuracy–speed condition with the accuracy condition confirmed these impressions. The former analysis revealed a significant difference between the speed–accuracy condition and the speed condition, $F(1, 144) = 7.99, MSE = 63.89$, that was qualified by a significant interaction with practice block, $F(4, 576) = 4.64, MSE = 20.71$. The latter analysis showed a significant difference between the speed–accuracy condition and the speed condition, $F(1, 144) = 13.38, MSE = 63.89$, that was qualified by a significant interaction with practice block, $F(4, 576) = 6.49, MSE = 20.71$. In addition, the accuracy–speed condition differed significantly from the control condition, $F(1, 144) = 3.46, MSE = 63.89$ ($F < 2$, for the difference between the speed–accuracy and control conditions).

**RT.** Figure 2 displays the mean RTs in the five experimental conditions as a function of practice block. Because we did not obtain qualitative differences for correct and incorrect strings, individual median RTs were averaged across the two string types. The general pattern of results depicted in Figure 2 is very similar to the one for error rates shown in Figure 1. First, throughout practice, participants in the pure accuracy condition verified strings more slowly than participants in the pure speed condition. The control condition was almost exactly in between the two pure instruction conditions. Second, the mean RTs in the accuracy–speed and speed–accuracy conditions changed systematically when task instructions were modified, although the changes were much less dramatic than they were for error rates.

Two separate Condition × Practice Block mixed-design ANOVAs were again computed, one for Blocks 1–4 and a second one for Blocks 4–8. The Blocks 1–4 ANOVA yielded significant main effects of condition, $F(4, 144) = 14.31, MSE = 4,292,653.0$, and of practice block, $F(3, 432) = 235.82, MSE = 553,800.6$. The main effect of condition was, as is evident in Figure 2, due primarily to the difference between the combined speed and speed–accuracy conditions, on the one hand, and between the combined accuracy and accuracy–speed conditions, on the other hand, $F(1, 144) = 55.13, MSE = 4,292,653.0$. The difference between these two pairs of conditions did not interact with practice block, $p > .5$. Although the speed and speed–accuracy conditions just failed to differ significantly from the control condition, $F(1, 144) = 2.82, MSE = 4,292,653.0, p < .1$, the difference between the two accuracy conditions versus the control condition was significant, $F(1, 144) = 9.10, MSE = 4,292,653.0$.

The Blocks 4–8 ANOVA yielded significant main effects of condition, $F(4, 144) = 10.55, MSE = 3,731,489.0$, and of practice block, $F(4, 576) = 103.09, MSE = 188,755.6$, as well as a significant interaction between condition and practice block, $F(16, 576) = 3.48, MSE = 188,755.6$. Separate planned follow-up contrasts comparing the accuracy–speed condition with the accuracy condition and the speed–accuracy condition...
dition with the speed condition did not reveal significant interactions, all ps > .4. The small jumps in the latencies of the accuracy-speed (downward) and the speed-accuracy (upward) conditions that can be seen in Figure 2 were thus not significant. 

Taken together, the analyses of the overall error rates and RTs suggest that the manipulation of task instruction was effective. Participants under speed stress performed more quickly and committed more errors than participants under accuracy stress. Moreover, changing task instructions affected participants’ error rates and RTs as well, although the effect on the latter measure was small relative to the effect on the former.

**Information Reduction**

**Correct strings.** As discussed earlier, the string-length effect for RTs on correct strings can be considered an indirect measure of information reduction (Haider & Frensch, 1996, 1999). The string-length effect is expected to differ systematically across experimental conditions for correct strings but not for incorrect strings. For the latter, string length should not matter because the error in incorrect strings was fixed at the third string position. We computed the best fitting linear regression line across the three different string lengths separately for each participant in each practice block. Figure 3 contains the mean slopes for correct alphabetic strings in the five experimental conditions as a function of practice block; Figure 4 contains the corresponding mean slopes for incorrect strings.

Inspection of Figure 3 shows a pattern qualitatively similar to that obtained for overall error rates and latencies. First, with practice, all slopes declined, $F(7, 287) = 9.55, MSE = 20,977.3; F(7, 175) = 17.14, MSE = 9,647.6; F(7, 224) = 20.53, MSE = 26,274.2; F(7, 217) = 11.99, MSE = 10,747.1; and F(7, 105) = 7.91, MSE = 1,409.1,$ for the accuracy, speed, accuracy-speed, speed-accuracy, and control conditions, respectively.

Second, and more importantly, the five experimental conditions differed in degree of slope decline. In the two pure instruction conditions, the slope for the speed condition was smaller than the slope for the accuracy condition in the first trial block already and also declined much faster over practice than in the accuracy condition. The change of instruction after the fourth practice block in the accuracy-speed condition led to an immediate dip in the slope, resulting in a slight difference between this condition and the accuracy condition in Blocks 5–8. In the speed-accuracy condition, the slope remained relatively constant after the instruction was changed, yielding a slight difference between this condition and the speed condition in Blocks 5–8.

Although these results essentially mirror those reported for overall error rates and latencies, a surprising finding that is conveyed by Figure 3 concerns the control condition. In essence, participants in the control condition seemed to behave very similarly to the participants in the speed-accuracy condition. In fact, although the overall difference between these two conditions was
INFORMATION REDUCTION

Figure 4. Means of the best fitting regression slopes for incorrect strings (Experiment 1). Error bars represent 95% between-subjects confidence intervals; control = medium caps, accuracy = longest caps, speed = shortest caps, accuracy-speed = long caps, and speed-accuracy = short caps.

significant, $F(1, 40) = 4.19$, $MSE = 47,426.7$, it did not interact with practice block, $p > .2$.

In order to examine the effects of instruction on the slopes representing the string-length effect, we again computed two Condition X Practice Block ANOVAs separately for Practice Blocks 1–4 and Practice Blocks 4–8. The two ANOVAs yielded significant main effects of condition, $F(4, 144) = 12.08$, $MSE = 70,868.2$, and $F(4, 144) = 6.88$, $MSE = 51,753.6$, for Blocks 1–4 and 4–8, respectively, and of practice block, $F(3, 432) = 27.35$, $MSE = 22,556.5$, and $F(4, 576) = 17.78$, $MSE = 9,765.7$, for Blocks 1–4 and 4–8, respectively. In addition, the Condition X Practice Block interaction was significant in both analyses, $F(12, 432) = 2.87$, $MSE = 22,556.5$, and $F(16, 576) = 2.51$, $MSE = 9,765.7$, for Blocks 1–4 and 4–8, respectively.

Planned comparisons following up the Blocks 1–4 analysis confirmed the impression conveyed by Figure 3 that the two combined speed-stress conditions differed significantly from the two combined accuracy-stress conditions, $F(1, 432) = 3.89$, $MSE = 22,556.5$. The two speed-stress conditions and the two accuracy-stress conditions did not differ significantly from each other, both $ps > .1$.

Planned comparisons following up the Blocks 4–8 analysis revealed a significant Condition X Practice Block interaction when only the accuracy-speed and the accuracy conditions were compared, $F(4, 576) = 3.17$, $MSE = 9,765.7$. The corresponding interaction for the comparison between the speed-accuracy and speed conditions was not significant, $p > .2$.

Taken together, the analyses on the slopes for correct alphabetic strings show that the manipulation of task instruction yielded results that were qualitatively consistent with our expectations. However, the within-subjects manipulation of task instruction was less effective than the between-subjects manipulation. In addition, the effects of speed stress and accuracy stress were not symmetrical relative to the control condition. There are two different possible explanations for this finding that we cannot distinguish on the basis of our data. The first explanation takes the nature of the control condition seriously by arguing that accuracy instructions slow the process of information reduction, whereas speed instructions have no effect. The second possible explanation holds that participants who are asked to maximize both speed and accuracy are more likely to orient themselves toward maximizing speed of performance rather than toward maximizing accuracy. The second explanation, thus, questions the validity of the control condition. In retrospect, it seems clear that without additional information on the behavior of individual participants, the usefulness of the control condition is limited. Consequently, we did not use a control condition in Experiment 2.

Incorrect strings. Figure 4 displays the slopes for incorrect alphabetic strings as a function of practice in the five experimental conditions. In contrast to the slopes for correct strings, the slopes for incorrect strings did not vary with instruction and, furthermore, declined only from the first to the second practice block. One-way (practice) ANOVAs, computed separately for
each condition, indicated a significant decline of mean slope for all but the speed–accuracy condition, $F(7, 105) = 3.70, \text{MSE} = 15,368.2; F(7, 287) = 6.89, \text{MSE} = 25,135.7; F(7, 175) = 4.30, \text{MSE} = 15,564.4; \text{and } F(7, 224) = 6.28, \text{MSE} = 37,980.5$, for the control, accuracy, speed, and accuracy–speed conditions, respectively (in the speed–accuracy condition, $F < 1.50, p > .2$).

Two separate Condition $\times$ Practice Block ANOVAs (for Blocks 1–4 and Blocks 4–8) yielded only significant main effects of practice block, $F(3, 432) = 12.63, \text{MSE} = 33,039.4$, for Blocks 1–4, and, $F(4, 576) = 4.33, \text{MSE} = 12,708.4$, for Blocks 4–8. All other effects were not significant (all $Fs < 1.50$), indicating that the slopes for incorrect strings did not vary systematically as a function of task instruction.

**Discussion**

Experiment 1 produced four main results: First, the initial between-subjects manipulation of task instruction affected overall performance in terms of both error rate and latency. Participants stressed for speed performed less accurately and more quickly than participants stressed for accuracy. Second, the initial manipulation of task instruction affected amount of information reduction as well. Participants stressed for speed showed a larger reduction in the string-length effect for correct strings than did participants stressed for accuracy. Third, changing task instructions after Block 4 affected overall error rates and also had effects, albeit relatively small, on latencies and on the magnitude of the string-length effect. Thus, participants were able to modify their behavior in accordance with new instructions—at least to some extent. Fourth, the effects of speed stress and accuracy instructions were nearly symmetrical relative to the control condition on measures of overall error rate and latency but not on the measure of information reduction.

In general, the results of Experiment 1 are consistent with the interpretation that task instruction affects both the setting of a response criterion and the selection of which information is processed. It appears that, under speed stress, participants adopt a liberal response criterion and, in addition, quickly cease processing of task information that they deem irrelevant. Under accuracy instructions, participants adopt a conservative response criterion and also process all or most of the given task information. These findings are in accordance with our rational analysis provided above, in which we suggested that in order to avoid systematic errors, the setting of a liberal response criterion needs to be accompanied by neglect of task-irrelevant information. In contrast, the setting of a conservative response criterion makes most sense if all available task information is processed. At a somewhat higher theoretical level, the obtained findings are also consistent with the information-reduction view that we proposed earlier (Haider & Frensch, 1996), according to which the decision to limit task processing to task-relevant information is based, at least partly, on strategic considerations, and therefore can be influenced by manipulating task instructions.

One potential problem with the interpretation that type of instruction affects degree of information reduction as referred to above is that methodologically, the effects of instruction on overall latency and on information reduction are difficult to separate. The reason for this is that a decreasing string-length effect, which we take as evidence for information reduction, is also an unavoidable consequence of declining latencies. That is, as latencies decrease, the difference in RT for shorter and longer strings decreases as well.

One possibility to separate task instruction influences on the string-length effect from task instruction influences on overall latency is to statistically equate all experimental participants in terms of their overall latencies and then compute the individual string-length effects. To do this, we first converted individual RTs separately for each block into $z$ scores and then computed string-length effects. The results of this analysis are shown in Figure 5 (correct strings) and Figure 6 (incorrect strings). When compared with corresponding Figures 3 and 4, it is clear that the pattern of results for the string-length effect is virtually the same. Thus, we can be reasonably confident that the effect of task instruction on the string-length effect is not a statistical artifact of the effect of task instruction on overall latency.

The main purpose of Experiment 2 was to replicate the results of Experiment 1 with a
different sample. A second purpose was to further explore one surprising finding in the present experiment: Specifically, although participants’ behavior in the mixed-instruction conditions was clearly affected by the change of instruction, the accompanying changes in performance and, more importantly, in information reduction were relatively small (see Figures 3 and 5). For example, one might have expected that changing to a speed instruction in the accuracy-speed condition would have immediately resulted in a string-length effect that was indistinguishable from that in the pure speed condition.

One possible explanation for the pronounced difference in information reduction between the speed and accuracy-speed conditions during the second half of practice is that relatively few participants in the accuracy-speed condition might have realized during Blocks 1–4 that some of the letters were irrelevant. Therefore, they were not able to limit their task processing to the relevant information when this would have helped them to improve their speed of processing. The assumption that noticing task-irrelevant information occurs to a larger extent under speed than under accuracy instruction is, however, not very appealing and clearly lacks face validity. Alternatively, one might therefore assume that manipulating only task instruction might not have been sufficient to force participants in the accuracy-speed condition to ignore the task-irrelevant letters even if they were relatively certain that the letters were irrelevant.

In Experiment 2, we concentrated on the switch from an initial accuracy to a later speed instruction and tried to design conditions that would equate the string-length effect in the accuracy-speed and speed conditions during the
For this purpose, we examined whether additional time pressure under speed-instruction would eliminate the differences in string-length effect between the accuracy–speed and speed conditions during the second half of practice. We assumed that additional time pressure would increase the likelihood that participants would ignore task-irrelevant information—provided they had discovered the irrelevant information. To this end, we systematically decreased the time that strings were visible on the screen under speed instructions. In the pure speed instruction condition, presentation time was decreased from 2,000 ms in the first practice block by 100 ms in each subsequent trial block. In the accuracy–speed condition, presentation time was initially 6,000 ms for the first half of practice and was then identical to that of the pure speed condition in the second half of practice. Under accuracy instructions, presentation time was held constant throughout the entire experiment (fixed at 6,000 ms). Thus, in the speed–accuracy condition, presentation time was identical to that for the pure speed condition during the first half of practice and was fixed at 6,000 ms during the second half of practice.

If the difference in string-length effect between the speed condition and the accuracy–speed condition during the second half of practice was due to participants' difficulty in the accuracy–speed condition to ignore task-irrelevant information even though they deem this information as task irrelevant, then adding time pressure should lead to equal performance or at least to a reduced difference in performance relative to Experiment 1. If, on the other hand, the difference between the accuracy–speed condition and the speed condition was due to a difference in detecting task-irrelevant information during the first half of practice, then the difference between the two conditions during the second half of practice should be just as pronounced as it was in Experiment 1.

Experiment 2

Experiment 2 was identical to Experiment 1, with the exception described above. In addition, we did not use a control condition in Experiment 2.

Method

Participants

Sixty female and 26 male undergraduate students at the University of Missouri at Columbia served as participants. All students received course credit in an introductory psychology class. Participants ranged in age from 18 to 34 years ($M = 19.5$ years, $SD = 2.82$). Because of technical problems, data from 3 participants were lost.

Materials

Stimuli and apparatus were identical to those used in Experiment 1.

Procedure

The procedure and presentation of strings followed the format described for Experiment 1, with the exception noted above.

Design

Dependent variables were mean error rate and median RT per practice block. Independent variables were experimental condition (accuracy, speed, accuracy–speed, speed–accuracy; between subjects), practice block (one to eight; within subjects), string type (correct vs. incorrect).

2 We concentrated on the change from accuracy to speed instructions because we assumed that it would be easier to convince participants who knew about the irrelevant letters to no longer process these letters than it would be to convince participants who had ignored—without obvious drawback—the irrelevant letters for some time to now not ignore this information any longer. Our results concerning the switch from speed to accuracy instruction in Experiment 1 seemed to show that it may well be that participants who had successfully ignored the irrelevant information for four trial blocks simply did not understand why they should now process information they knew was irrelevant. The finding that the string-length effect remained at the Block 4 level when the task instruction was changed is consistent with the explanation that participants in the speed–accuracy condition who had come to ignore the irrelevant information continued to do so.
within subjects), and string length (three, five, or seven; within subjects).

Results

As in Experiment 1, overall error rates were first computed for each participant and each practice block. Participants were excluded from all subsequent data analyses if their mean error rate was higher than 15% in all eight practice blocks (n = 1, n = 13, n = 5, and n = 8, in the accuracy, speed, accuracy–speed, and speed–accuracy conditions, respectively). This resulted in 19 participants remaining in the accuracy condition, 8 participants remaining in the speed condition, 16 participants remaining in the accuracy–speed condition, and 13 participants remaining in the speed–accuracy condition. For all remaining participants, median RTs were computed for correct responses to correct and incorrect alphabetic strings, separately for each practice block and each string length.

As argued above, manipulating task instructions bears the danger of generating speed–accuracy trade-offs that can make comparison of RTs and error rates across conditions meaningless. In order to examine speed–accuracy trade-offs, the correlation between mean error rate and mean latency was computed separately for each condition and separately for Blocks 1–4 versus 5–8. The results are shown in Table 1. As can be seen, none of the computed correlations was significant. Thus, despite the higher speed stress that was realized in Experiment 2, no significant speed–accuracy trade-off occurred.

The discussion of the main results follows the same pattern as in Experiment 1. First, we discuss the effects of manipulating type of task instruction on overall mean error rates and RTs. Then, we compare the string-length effects in the four experimental conditions.

Overall Error Rate and RT

Error rate. Figure 7 displays the mean percentage error rate in the four experimental conditions as a function of practice block. Again, individual error rates were averaged across the two string types because an initial analysis had not revealed any qualitative differences for correct and incorrect strings.

Figure 7 shows an error pattern that is practically identical to that displayed in Figure 1. As can be seen in the figure, the mean error rate was higher in the speed condition than in the accuracy condition, indicating that the between-subjects manipulation of instructions was effective. A comparison of the error rates for the mixed- and the pure-instruction conditions shows that participants were able to modify their performance in accordance with the new task instructions. In the accuracy–speed condition, the error rate was, during the first four blocks, indistinguishable from that in the pure accuracy condition and increased almost to the level of the pure speed condition when task instruction was changed. Similarly, in the speed–accuracy condition, the error rate was initially identical to that in the pure
speed condition and decreased to the level of the pure accuracy condition in Blocks 5–8.

In order to separately assess the effects of the initial task instruction manipulation and the subsequent change of task instruction, we again computed separate Condition × Practice Block ANOVAs for Blocks 1–4 and Blocks 4–8. The Blocks 1–4 analysis revealed only a significant main effect of condition, $F(3, 52) = 34.12$, $MSE = 28.57$. A planned comparison confirmed that the difference between the two combined accuracy and the two combined speed conditions was significant, $F(1, 52) = 82.86$, $MSE = 28.57$. The speed and speed-accuracy conditions did not differ significantly from each other nor did the accuracy and accuracy-speed conditions, both $p > .2$.

The Blocks 4–8 ANOVA revealed a significant main effect of condition, $F(3, 52) = 4.27$, $MSE = 71.48$, and a significant interaction between condition and practice block, $F(12, 208) = 3.56$, $MSE = 22.30$.

Separate planned follow-up contrasts comparing the speed-accuracy condition with the speed condition and the accuracy-speed condition with the accuracy condition confirmed the impression that changing task instruction had an immediate effect on participants' error rates. The former analysis revealed a significant difference between the speed-accuracy and speed conditions, $F(1, 52) = 4.30$, $MSE = 71.48$, that was qualified by a significant interaction with practice block, $F(4, 208) = 2.65$, $MSE = 22.30$. The latter analysis, the difference between the accuracy-speed and accuracy conditions, just failed significance, $F(1, 52) = 3.43$, $MSE = 71.48$, $p < .1$, but yielded a significant Condition × Practice Block interaction, $F(4, 208) = 2.65$, $MSE = 22.30$.

On the whole, the results of the analyses on mean error rate replicate Experiment 1 and show that (a) the initial between-subjects manipulation of task instruction affected accuracy of performance and (b) participants were able to modify their behavior when task instructions were changed.

RT. Figure 8 displays the mean RTs in the four experimental conditions as a function of practice block. Again, individual RTs were averaged across the two string types because an initial analysis had not revealed any qualitative differences for correct and incorrect strings. The general pattern of results depicted in Figure 8 is very similar to the one for Experiment 1 shown in Figure 2. First, throughout practice, participants in the accuracy condition verified strings more slowly than participants in the speed condition. Second, the latencies in the accuracy-speed and speed-accuracy conditions changed systematically and qualitatively more dramatically than in Experiment 1 when task instructions were changed.

Two separate Condition × Practice Block mixed-design ANOVAs were again computed, one for Blocks 1–4 and a second one for Blocks 4–8. The Blocks 1–4 ANOVA yielded significant main effects of condition, $F(3, 52) = 5.47$, $MSE = 3,055,970.0$, and of practice block, $F(3, 156) = 85.30$, $MSE = 451,168.3$. The main effect of condition was due to the difference between the combined speed and speed-accuracy condi-

![Figure 8](image_url)

**Figure 8.** Mean reaction times (RTs; in milliseconds) for correct and incorrect strings (Experiment 2). Error bars represent 95% between-subjects confidence intervals; control = medium caps, accuracy = longest caps, speed = shortest caps, accuracy-speed = long caps, and speed-accuracy = short caps.
tions, on the one hand, and the combined accuracy and accuracy-speed conditions, on the other hand, \( F(1, 52) = 9.15, MSE = 451,168.3 \). The difference between these two pairs of conditions did not interact with practice block, \( p > .1 \).

The Blocks 4–8 ANOVA yielded significant main effects of condition, \( F(3, 52) = 6.90, MSE = 1,890,915.0 \), and of practice block, \( F(4, 208) = 39.53, MSE = 173,312.0 \). In addition, the Condition × Practice Block interaction was significant as well, \( F(12, 208) = 4.74, MSE = 173,312.0 \). As Figure 8 shows, the interaction between condition and practice block was caused primarily by an immediate increase in the mean RT of the speed-accuracy condition and decrease in the mean RT of the accuracy-speed condition when task instructions were changed.

Separate planned follow-up contrasts on the Condition × Practice Block interaction revealed a significant interaction between practice block and the difference between the speed-accuracy and speed conditions, \( F(4, 208) = 8.36, MSE = 173,312.0 \). The interaction between practice block and the difference between the accuracy-speed and accuracy conditions just failed to reach significance, \( F(4,208) = 2.30, MSE = 173,312.0, p < .06 \).

In summary, the results of the overall RTs replicated Experiment 1. Under speed stress, participants performed more quickly and with more errors than participants under accuracy stress. Furthermore, as was expected, changing task instructions had a larger effect on participants’ RTs than it had in Experiment 1. However, this was true for both the accuracy-speed and speed-accuracy conditions, although our manipulation had aimed primarily at the accuracy-speed condition.

### Information Reduction

**Correct strings.** The magnitude of the string-length effect was again used as an indirect measure of information reduction. As a reminder, the string-length effect was expected to differ systematically across experimental conditions for correct strings but not for incorrect strings. In order to separate type of instruction influences on overall latency from type of instruction influences on the string-length effect, we first converted individual RTs separately for each practice block into z scores and then computed string-length effects (see Discussion to Experiment 1). The results of this analysis are shown in Figure 9 for correct strings and Figure 10 for incorrect strings.

Inspection of Figure 9 shows a pattern that is essentially what we had expected to find. First, and replicating Experiment 1, the slope in the pure speed condition declined faster over practice than the slope in the pure accuracy condition. Second, the change of instruction after the fourth practice block in the accuracy-speed condition led to an immediate dip in the slope, resulting in only a very slight difference between this condition and the pure speed condition for Blocks 5–8. Surprisingly, although our presentation time manipulation was aimed at the accuracy-speed condition and not the speed-accuracy condition, the slope in the speed-accuracy condition also

![Figure 9](image-url)
changed dramatically after Block 4 and was not different from the slope in the pure accuracy condition for Blocks 5–8.

In order to examine the effects of instruction on the slopes, we again computed two Condition × Practice Block ANOVAs separately for Blocks 1–4 and Blocks 4–8. The Blocks 1–4 ANOVA yielded significant main effects of condition, \( F(3, 52) = 9.95, MSE = 0.0262 \), and of practice block, \( F(3, 156) = 3.43, MSE = 0.0107 \), as well as a significant Condition × Practice Block interaction, \( F(9, 156) = 2.14, MSE = 0.0107 \). The Blocks 4–8 ANOVA just failed to reach significance for the main effect of condition, \( F(3, 52) = 2.28, MSE = 0.0347, p < .09 \). Only the Condition × Practice Block interaction was significant, \( F(12, 208) = 4.22, MSE = 0.0123 \).

Planned comparisons following up the Blocks 1–4 analysis confirmed the impression conveyed by Figure 9 that the two speed-stress conditions differed significantly from the two accuracy-stress conditions, \( F(1, 52) = 26.20, MSE = 0.0262 \). The two speed-stress conditions and the two accuracy-stress conditions did not differ significantly from each other, both \( ps > .1 \).

Planned comparisons on the Condition × Practice Block interaction following up the Blocks 4–8 analysis revealed a significant interaction between practice block and the difference between the accuracy–speed and accuracy conditions, \( F(4, 208) = 4.41, MSE = 0.0123 \). The interaction between practice block and the difference between the speed–accuracy and speed conditions just fell short of significance, \( F(4, 208) = 2.15, MSE = 0.0123, p < .08 \).

On the whole, the analyses on the slopes for correct alphabetic strings replicate the results of Experiment 1 by showing that the initial between-subjects manipulation of task instruction was effective. In contrast to Experiment 1, the change of instruction, accompanied by additional time pressure, pushed the mean slope in the accuracy–speed condition down to the level of the pure speed condition. Surprisingly and unexpectedly, the slope in the speed–accuracy condition increased to the level of the pure accuracy condition as well.

Incorrect strings. Figure 10 displays the slopes for incorrect alphabetic strings as a function of practice in the four experimental conditions. As we had done for correct strings, we computed two separate Condition × Practice Block ANOVAs for Blocks 1–4 and for Blocks 4–8. The only significant effect we found was for practice block in the first analysis, \( F(3, 156) = 7.49, MSE = 0.0123 \). No other effects were significant (all \( Fs < 2.00; ps > .1 \)). Thus, as in Experiment 1, type of instruction did not affect the slopes for incorrect alphabetic strings.

Discussion

The primary purpose of Experiment 2 was to replicate the results of Experiment 1. A secondary purpose was to explore the effect of time pressure on information reduction and to examine whether a lack of force in Experiment 1 had caused the remaining differences in degree of information...
reduction between the accuracy–speed and pure speed conditions found for Blocks 5–8.

First, the results of Experiment 2 clearly replicated those of Experiment 1. Again, participants stressed for speed performed less accurately and faster than participants stressed for accuracy, indicating that participants were able to establish different response criteria for different instructions. Furthermore, type of instruction affected degree of information reduction. For correct strings, slopes were higher under accuracy stress than under speed stress. Second, as in Experiment 1, the within-subjects change of instruction had an immediate effect on the slopes in the accuracy–speed and speed–accuracy conditions. The slope of the accuracy–speed condition reached the level of the speed condition during the second half of the practice, probably because of the higher speed stress in the current experiment.

In addition, and quite unexpectedly, the slope for the speed–accuracy condition did not differ from that for the accuracy condition when task instruction was changed. The latter finding was surprising because one might expect that it is difficult to imagine any experimental manipulation that might force participants to process information that they assume is irrelevant. One possible reason for why the speed–accuracy condition did not differ from the accuracy condition for Blocks 5–8 in Experiment 2 as it did in Experiment 1 may be that participants in Experiment 2 were uncertain whether errors would now occur in the task-redundant letters and without time pressure in Blocks 5–8, used the additional time to evaluate these letters.

General Discussion

Taken together, Experiments 1 and 2 provided two main results: First, the manipulation of task instruction affected overall task performance in terms of RT and accuracy. Second, and more important in the present context, task instruction influenced the string-length effect for correct strings as well. These results were found not only when task instruction was manipulated between subjects but also when it was manipulated within subjects. The latter effects were particularly impressive in combination with additional time pressure under speed stress.

At a first level of explanation, the present findings are consistent with the assumption that task instruction affects both the setting of a response criterion (e.g., Pachella, 1974; Rabbitt, 1989; Sperling & Dosher, 1986) and the sampling of information from a presented stimulus. In the language of random walk models (Ratcliff, 1981, 1985; Treisman & Williams, 1984), participants who were asked to optimize their speed of task processing moved their response boundary closer to the starting point, meaning that their selection of a response was based on relatively little information about the stimulus. Participants who were instructed to optimize accuracy of performance, in contrast, were more likely to adopt a conservative response criterion, that is, to move their response boundary farther apart from the starting point to base their response selection on more information extracted from the task stimulus. Thus, the results suggest that the setting of response criteria not only affects the speed of processing but also the amount of information processed to generate a response, as is predicted by random walk models.

In the language of information reduction, participants who are instructed to optimize speed of processing try to reduce the amount of information they process. After having identified task-irrelevant information, they try to ignore it on the basis of relatively little prior experience. If they have not identified the irrelevant information yet, they appear to sample randomly from the stimulus information and become extremely inaccurate, as was the case in the speed condition of Experiment 2. Participants who are instructed to optimize accuracy of processing, in contrast, are unlikely to reduce the amount of stimulus information they process.

A rational analysis suggests, and the present findings support this view, that the setting of a response criterion and the reduction of processed information should not be independent. Indeed, a liberal response criterion appears to be accompanied by neglect of task-irrelevant information. In contrast, the setting of a conservative response criterion seems to imply that all available task information is processed. These findings extend the view expressed by Strayer and Kramer (1994a, 1994b) that more liberal settings of response criteria are one characteristic of advanced skill.

At a second level of explanation, the present findings are consistent with our information reduc-
tion hypothesis (Haider & Frensch, 1996). This view holds that the decision to limit task processing to task-relevant information is based on strategic considerations and therefore can be manipulated by task instructions. The current findings, particularly the decrease of the mean slope in the accuracy-speed condition and the increase of the mean slope in the speed-accuracy condition in Experiment 2, clearly demonstrate that information reduction is at least partly under voluntary control.

Finally, the present results suggest that cognitive skill acquisition may, in general, be based not only on data-driven learning mechanisms (e.g., Logan, 1988), as has been argued sometimes, but also on strategic considerations. The latter possibility has recently been discussed by Strayer and Kramer (1994a, 1994b) and Doane, Alderton, Sohn, and Pellegrino (1996). Doane et al. (1996), for instance, demonstrated that an initially adopted learning strategy influences which information a learner attends to when the task consists of discriminating targets from distractors (see also Fisher & Tanner, 1992).

Practical Implications

The findings presented here are important because of their potential practical implications for many areas of human performance, such as the domain of expertise or instructional psychology (e.g., Bransford et al., 1986; Larkin, 1983; Myles-Worsley et al., 1988; Shanteau, 1992; Shapiro & Raymond, 1989). The results strongly suggest that with practice, humans learn to ignore information that has no diagnostic value (e.g., redundant task information) with respect to a given goal. Importantly, the amount of evidence that is needed to judge information as task-redundant and to ignore this information depends on task instruction. In contrast to schema theory (Minsky, 1975; Rumelhart, 1975; Schmidt, 1975, 1988), which focuses primarily on knowledge representation, that is, on the result of learning, the purpose of the present experiments was to show that information reduction is a general and nonspecific-domain learning process that takes place during practice. The information reduction hypothesis holds that learning to limit task processing to task-relevant information is based on the detection that task information contains irrelevant information. This process is assumed to be a data-driven process (bottom-up) that is followed by a second strategical process, limiting task processing to the task-relevant information. The latter assumption is strikingly confirmed by the results reported here. Thus, our findings on information reduction extend schema theory and are important for domains in which routine activities play a major role.

For example, for the domain of instructional psychology, Bransford et al. (1986) criticized that many teaching activities fail to educate students to attend to the relevant information. For example, students learning to solve word problems in arithmetic have difficulties differentiating between task-relevant and task-irrelevant numeric facts. They are taught abstract schemata or rules of how to find the relevant facts. However, despite these schemata, the students are poor in differentiating between relevant and irrelevant facts in concrete tasks. As the current findings on information reduction suggest, an alternative way to teach students to identify the relevant facts in arithmetic word problems might be to train students with a repeated number of problems containing the same structure. In this case, students learn to identify the relevant facts in a bottom-up manner. In contrast to schema theory, learning in this situation is equivalent to a differentiation of perception (J. J. Gibson & Gibson, 1955), such that the learner becomes increasingly sensitive to relevant environmental cues.

Moreover, as we discussed earlier, information reduction is consistent with several findings in the domain of expertise (e.g., Ericsson & Lehmann, 1996; Ericsson & Smith, 1991; Patel & Groen, 1991). A robust difference between experts and novices is that experts focus on relevant task information and ignore task-irrelevant information. For example, De Maio, Parkinson, Leshowitz, Crosby, and Thorpe (1976) compared the visual scanning processes of student and instructor pilots. They found that, particularly under time pressure, the scanning strategies of instructor pilots did not follow the rules they had been taught. Instead, they fixated only task-relevant information while neglecting the less important instruments. This allowed the instructor pilots to manage situations with high time pressure, whereas student pilots who scanned all instru-
ments failed to manage these situations. However, it is unclear exactly how experts learn to efficiently use information or how to teach someone to process relevant information only (e.g., E. J. Gibson, 1963; J. J. Gibson & Gibson, 1955; Shapiro & Raymond, 1989). It is our hope that insights in the relation between external facilitating and inhibiting conditions may eventually allow us to control the degree to which factual and seemingly task-irrelevant information is ignored. The present experiments on information reduction are a first step in this direction.

References


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- **For Experimental and Clinical Psychopharmacology**, submit manuscripts to Warren K. Bickel, PhD, Department of Psychiatry, University of Vermont, 38 Fletcher Place, Burlington, VT 05401-1419.

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- **For the Journal of Experimental Psychology: Human Perception and Performance**, submit manuscripts to David A. Rosenbaum, PhD, Department of Psychology, Pennsylvania State University, 642 Moore Building, University Park, PA 16802-3104.

Manuscript submission patterns make the precise date of completion of the 1999 volumes uncertain. Current editors, Charles R. Schuster, PhD; Clara E. Hill, PhD; and Thomas H. Carr, PhD, respectively, will receive and consider manuscripts through December 31, 1998. Should 1999 volumes be completed before that date, manuscripts will be redirected to the new editors for consideration in 2000 volumes.