INDIVIDUAL DIFFERENCES IN ATTENTIONAL FLEXIBILITY,

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Abstract

This report describes a preliminary study that attempts to develop the concept of attentional flexibility. Flexibility refers to the rapidity with which set or attention can be switched from one signal requiring attention to another. If a trait exists, then people that can rapidly switch set on one task should also be able to rapidly switch set in a different kind of setting. The existence of such a trait could ultimately be very useful as a predictor of performance on a variety of skilled tasks, and some evidence for that has been found by Kahneman, Gopher, and colleagues. We studied flexibility on four tasks: (1) The difficulty in dealing with an unexpected signal after just being primed for another; (2) The difficulty in dealing with a rarely occurring event that occurs in the context of much more frequent events; (3) The ability to prepare for signals in another category immediately after responding to a signal in a different category, even when the need for preparation is predictable; and (4) The ability to switch attention from one dichotic message to another. This preliminary study provides some promise for the concept of flexibility, so we are currently engaged in follow-up studies.
Introducction

The last few years have generated considerable interest in an information-processing approach to the study of individual differences. What is meant by an information-processing approach? There are two closely related ideas. One idea bases the study of individual differences on current theory regarding cognitive processes. In the past much investigation of individual differences was rather distant from the mainstream of experimental psychology and its theory; indeed, some people argue that much past study of individual differences had little basis in any theory of how the mind operates.

The second idea underlying an information-processing approach involves the measurement of processes that comprise task performance. Usually in past studies of individual differences, whole task scores from a variety of tasks were correlated with each other to determine whether the tasks had processes in common. Such correlations tend to be low because although two tasks may have processes in common that produce a correlation, they also involve different processes that reduce the correlation. An information-processing approach, in contrast, attempts to derive process scores, not task scores, and correlate such scores derived from different tasks to infer a common process. To the extent that theory has postulated appropriate processes and to the extent the measurement methods isolate the processes, correlations should be higher than traditional correlations between tasks.

Basically, Donders' historic subtractive method is used to isolate process scores. Theory is used to select two or more conditions of the same task to reflect different levels of difficulty on a single process. Subtracting the two scores from each other yields a derived measure of the process. Sometimes several conditions that manipulate difficulty along a single process are run, and a function is fit to the results and used to estimate a parameter that reflects the process. But a parameter estimate from a function is basically an estimate derived from subtracting conditions, except that more than two conditions are used. Two examples of the subtractive method are: (1) The subtraction of physical match reaction times in Posner's letter matching paradigm (Posner & Mitchell, 1967) from name match reaction times yields a measure of the relative
speed of access to a name code; (2) Fitting the equation \( RT = a + bH \) to reaction time (RT) as a function of stimulus uncertainty (H) yields a parameter \( b \) that estimates choice time.

We have begun a project using information-processing analysis to study individual differences in attentional flexibility. This project is still underway; the data we have to report are from a preliminary study that yielded promising results but at the same time clearly indicates needed changes in our studies to firmly establish a trait of attentional flexibility.

The germination point for our research came from studies by Gopher and Kahneman (1971) and Kahneman, Ben-Ishai, and Lotan (1973). They devised a dichotic listening task that involved two parts in each trial. In Part 1 a high or low tone occurred informing subjects whether to report digits from the left or right ear. Then a series of word pairs or digit and word pairs occurred at a rapid rate and subjects reported back only the digits that occurred in the indicated ear. After several pairs another tone occurred with no pause in the rate to initiate Part 2. In Part 2 three digit pairs were presented, and subjects reported the three digits from the ear cued by the second tone. Number of errors on Part 2 correlated modestly with accident ratings of Israeli bus drivers, with flight school success of student pilots, and with skill assignment of professional pilots. Part 1, on the other hand, correlated less well with the criterion tasks.

Why did Part 2 but not Part 1 correlate with flying and driving skills? Kahneman and colleagues suggested that Part 2 requires switching attention (or set) from an already committed state. Part 1 does not. Ease of switching attention in the dichotic task may be related to flying and driving because they can benefit from flexible changes in set. For example, an accident in bus driving may more likely be avoided by a person that can quickly switch attention from the task at hand to an unexpected event.

If this notion is correct, it implies that people reliably differ on a trait of attentional flexibility, and that trait is common both to Part 2 of the dichotic listening task and both flying and driving. The present study was devised to determine in a more fundamental manner whether a trait of flexibility exists.

In general flexibility may be identified with the ease with which one can switch set from one expectation to another. Moreover, we concerned ourselves with situations in which set is changed in a time range of milliseconds to perhaps a second. Our eventual hope is that this type of flexibility might be
predictive of performance in fast action motor skills such as driving, flying, or many dynamic sports.

Switching of set can occur in two different manners. In one case people may expect a particular signal type and then get an unexpected signal. Posner and Snyder (1975) and LaBerge (1973) have extensively analyzed this paradigm. People typically are fast in responding to an expected signal—i.e., they show RT benefit compared to neutral expectations. But RT to unexpected signals exhibits cost compared to the neutral signal. Our initial notion was that RT cost is a measure of flexibility. People that suffer little cost can rapidly switch set to deal with an unexpected event. We devised two different situations that involved switching set from one signal to an unexpected signal and measured both RT costs and benefits of expectations.

The other case of interest is one in which set is switched in a predictable manner. In essence one can ask whether flexibility refers to dealing with unexpected signals (i.e., cost) or whether it refers simply to switching of set regardless of whether the switch is predictable or not. We devised one situation that required constant switching of set but the signal source to which attention should be directed was perfectly predictable.

Finally we examined a version of Kahneman and colleagues' dichotic listening task.

If a general trait of flexibility exists, then the various derived measures of cost and benefit should correlate with one another. Let's turn to consider in more detail the actual tasks used.

Tasks

A total of 15 subjects were run through four tasks extending over several sessions. Each task was designed to yield one or more measures of flexibility. Then these measures of flexibility were correlated with each other. Most of the measures involved subtracting one condition from another. Several of the measures were prompted by Posner and Snyder's theoretical treatment of attention switching in terms of costs and benefits.

The Priming Task

One task was closely analogous to the cost-benefit paradigm of Posner and Snyder. On each trial a warning signal occurred. On half the trials the warning
was a neutral plus indicating that any of four possible signals was equally likely. Those signals were a red light, a square, triangle, or trapezoid. The red light required a toggle switch press with the left hand and the forms required key-press responses with the right hand. Both the red light and the forms were centered on a scope face. On the other half of the trials the warning signal was the word red, cueing the subjects that the red light would follow with a probability of .70. If the red light failed to occur, the forms occurred with equal probability. These two trial types, cued and noncued, were randomly intermixed. The warning signal occurred 500 msec before a signal requiring a response.

Benefit was calculated by subtracting reaction times to the red light when it was cued from reaction times to the red light under neutral expectations. Cost was calculated by subtracting reaction time to neutral forms from reaction time to unexpected forms.

**Rare Event Task**

The second task used the same stimuli—red light, square, trapezoid, and triangle—and the same response assignments. On 99% of all trials, one of the three forms occurred. Response to one signal was followed 20 msec later by another stimulus. On only 1% of the trials, averaging once every two blocks of trials and 12 times a session, did a red light occur. Because in the context subjects were expecting forms, reaction time to red lights suffered large cost. Half the trials were preceded by a plus sign warning for any of the three forms and the other trials were preceded by a word warning for a particular one of the three forms. Although cost to the red light was larger when subjects were prepared for a particular form than for any form, the variable had little effect on other results and will be ignored.

Cost to the red light can be calculated by subtracting the neutral reaction time to red lights in the priming study from reaction time to the red light when it rarely occurred in the rare event task. Cost calculated in this manner tended to be four or five times larger than cost in the priming study.

**Alternation Task**

Both preceding tasks measured flexibility by the additional time required to respond to an unexpected signal. The alternation task required switching set but not in an unpredictable manner. Subjects were presented with six sig-
nals. Three colored lights—red, green, and yellow—were assigned to keys operated by the left hand and three forms—square, triangle, and trapezoid—were assigned to keys operated by the right hand.

In pure blocks subjects expected and responded only to colors or only to forms. In alternating blocks subjects responded to both colors and forms, but the two signal types strictly alternated. Response to a color was followed by a form and vice versa.

One way of viewing the difference between the two conditions is this: Should alternating blocks be viewed as six-choice or three-choice? If subjects efficiently switch attention, then the alternating condition is like three-choice. But if they fail to constantly use the predictability inherent in the situation and alternate attention, the task is like six-choice. In general alternating reaction time minus pure block reaction time yields a measure of flexibility.

In this task no warning signals were employed, but two different response-stimulus intervals were used. At the fast rate only 50 msec transpired between one response and the next stimulus. At the slow rate 750 msec transpired. The slow rate provides time for switching set, but even at that rate all subjects had slower RTs in the alternating condition than in the pure block condition. This suggested it would be useful to try two measures of flexibility. One measure was simply alternation reaction times at the fast rate minus pure block reaction times at the fast rate. The other measure adjusted the first one by additionally subtracting slow rate alternating RTs minus pure RTs. The rationale of the adjustment was that some people do not alternate attention very effectively even at slow rates where ample time should be available. The adjusted measure therefore reflects flexibility that was due to the high rate of action rather than one's reluctance to optimally prepare set.

**Dichotic Listening Task**

Our final task was a version of the Gopher and Kahneman dichotic listening task. This version was constructed by Dick Pew at Bolt, Beranek and Newman and kindly lent to us. Pairs of words, either pairs of color names or a color name and a digit, were presented at two pairs per second with one member of a pair directed to each ear through earphones. A high or low tone indicating from which ear to report the digits started a string of pairs, and then as the input progressed the subjects spoke the indicated digits aloud. After three, four, five, or six pairs another tone occurred at the same timing interval as
the pairs. Altogether four tones occurred in a block before subjects were
given a brief rest pause before another block.

The primary measure of flexibility is simply number of errors in reporting
the correct digits. The measure combines both errors of digit omission and
of reporting the wrong digit.

**Expectations**

If people differ from one another on a general trait of flexibility, then
we would expect the various measures of flexibility derived from the different
tasks to correlate with one another.

**Results**

The flexibility scores for each reaction time task can be derived from
either reaction times or errors. When both scores are used a large number of
correlations exist. Correlations involving error scores generally were smaller
than correlations involving only reaction time scores, so to simplify the data
presentation only reaction time correlations are shown in Table 1.

The priming task yields two scores, cost and benefit. The rare event task
yields a single score of cost. Two measures were derived from the alternating
colors and forms task, one in which alternation minus pure block reaction times
at the fast rate were measured and one in which that score was adjusted by the
alternation minus pure block scores at the slow rate. A single error score
was used for the dichotic listening task.

The major diagonal in the table lists the reliability of the tasks. The
reliabilities were all quite good except for very low reliability of the pri-
miming cost measure. The other correlations are between tasks, and they adopt
the convention that positive correlations fit the hypothesis and negative cor-
relations do not.

In general the correlations are not large, but several encourage us that
we are tapping a common factor of flexibility.

One surprise is that priming task cost did not correlate with the scores
from other tasks. This may partly be due to the extremely low reliability
of the prime cost score. On the other hand, prime benefit showed some tendency
to correlate with the other scores and that also was unexpected. Why might
benefit, which one would think measures preparation, correlate with the other
scores that measure ability to switch attention? One clue is that the priming
Table 1

Correlations Between Derived Scores of Flexibility

<table>
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<tr>
<th></th>
<th>Prime benefit</th>
<th>Prime cost</th>
<th>Rare event</th>
<th>A-P fast</th>
<th>A-P fast minus A-P slow</th>
<th>Dichotic Listening</th>
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<td>Prime benefit</td>
<td>.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime cost</td>
<td>.75*</td>
<td>.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rare event</td>
<td>.45*</td>
<td>-.20</td>
<td>.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-P fast</td>
<td>.44</td>
<td>-.01</td>
<td>.31</td>
<td>.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-P fast minus A-P slow</td>
<td>.59*</td>
<td>-.20</td>
<td>.61*</td>
<td>.77*</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>Dichotic listening</td>
<td>.43</td>
<td>-.22</td>
<td>.21</td>
<td>.47*</td>
<td>.45*</td>
<td>.92</td>
</tr>
</tbody>
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Underlined values are reliabilities.

* p < .05
study is itself a rather fast moving task that requires one to attend to a new prime about every second. People that are relatively inflexible may be deficient in using the prime and hence show low benefit. They also would tend to show low prime cost because a prerequisite of cost is that the prime cue is effectively used. Although flexibility may show up in benefit on the priming task, it would show up on cost on the rare event task. On the rare event task subjects have the context of hundreds of trials all with the same expectation for forms. They do not have to drive attention to expect a form in response to a priming cue. Since no person should have difficulty in expecting the likely source of signals, everyone should have large benefit, and flexibility then would show up only in dealing with unexpected signals—i.e., in cost.

Both measures on the alternating task also correlated moderately well with some of the other scores, and this was particularly true for the fast rate flexibility score adjusted for slow rate use of the predictability inherent in alternation. The important conclusion to be derived from these observations is that flexibility appears to reflect the proficiency with which one can switch set, whether switching is predictable or not, and not just the proficiency of dealing with unexpected signals.

Performance on the dichotic listening task also correlated with other tasks, though generally to a lesser degree. However, another problem occurred in conjunction with that task. Not only did the derived scores shown in Table 1 correlate with dichotic performance, but straight reaction time, which measures overall speed and not cost or benefit, correlated even more highly with the dichotic listening scores. When reaction time was partialed out, little or no predictability of the flexibility scores for dichotic listening remained. This was not true for correlations among other measures: Overall reaction speed had little influence on the correlations between the flexibility data. Some reflection reveals a possible reason why the dichotic task is influenced by speed, and flexibility scores offer little beyond that. The dichotic task is forced in pace and errors result when subjects have insufficient time to deal with a signal. People that are relatively slow in encoding one signal on the dichotic task may have less time available for dealing with a succeeding signal whether that signal is a word or tone. Problems in dealing with the dichotic task may therefore derive not from being slow in attention shifts but from having inadequate time for a shift even if one is relatively fast in shifting.

The data presentation here is rather cursory, ignoring details of error
rates on most of the tasks, alternate scoring systems, and partial correla-
tions. More detailed analysis, however, would not clarify issues. The corre-
lations between tasks are sufficiently large to indicate promise for the con-
cept of attentional flexibility as a trait. However, the correlations are not
as large or consistent as we would desire so that clearly further investiga-
tion is required. This report constitutes a preliminary presentation of what
we are attempting and the promise shown. In our ongoing work we have tried to
improve individual paradigms to eliminate some problems with each. We have
dropped the dichotic listening task as a good one for tapping flexibility be-
cause of its correlations with speed. And we have added new tasks.

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