Divergent thinking: strategies for generating alternative uses for familiar objects.

K. J. Gilhooly[1], E. Fioratou[1], S. H. Anthony[1] and V. Wynn[2]

[1]University of Hertfordshire, [2]Oxford Brookes University

Contact address: K. J. Gilhooly, School of Psychology, University of Hertfordshire, College Lane, Hatfield, Herts., AL10 9AB, England, UK. Email: k.j.gilhooly@herts.ac.uk

Abstract

Although the Alternative Uses divergent thinking task has been widely used in psychometric and experimental studies of creativity, the cognitive processes underlying this task have not been examined in detail before the two studies are reported here. In Experiment 1, a verbal protocol analysis study of the Alternative Uses task was carried out with a think aloud group (N = 40) and a silent control group (N=64). The groups did not differ in fluency or novelty of idea production indicating no verbal overshadowing. Analysis of protocols from the think aloud group suggested that initial responses were based on a strategy of Retrieval from long term memory of pre-known uses. Later responses tended to be based on a small number of other strategies: Property- use generation, imagined Disassembly of the target object into components and scanning of Broad Use categories for possible uses of the target item. Novelty of uses was particularly associated with the Disassembly strategy. Experiment 2 (N = 103) addressed the role of executive processes in generating new and previously known uses by examining individual differences in category fluency, letter fluency and divergent task performance. After completing the task participants were asked to indicate which of their responses were new for them. It was predicted and found in regression analyses that letter fluency (an executively loading task) was related to production of 'new' uses and category fluency was related to production of 'old' uses but not vice versa.

The ability to generate many different possible solutions to a problem is an important aspect of creative thinking and has been specifically addressed in the psychometric tradition by means of *divergent thinking* tests (Guilford, 1971; Guilford, Christensen, Merrifield & Wilson, 1978) in which participants are asked to generate as many alternative solutions as they can (Plucker & Renzulli, 1999). These tests contrast with *convergent thinking* tests in which there is but a single solution, e.g., Raven's Matrices (1960) and other standard intelligence tests. The Alternative Uses task is a prototypical divergent task in which the goal is to generate many possible uses, different from the common use, for familiar objects. In this task, the responses produced may be completely novel for the individual; for example, with the target item "barrel", a use as "a source of termite food" might be produced by a participant who had never before seen, heard or thought of such a use. In Boden's (2004, p.2) terminology, divergent production tasks can therefore involve "*personal-psychological creativity*", i.e., producing an idea that is new to the person who produces it, irrespective of how many people have had that idea before. In validation studies, divergent tests have been found to be better correlated with real life measures of creative behavior, such as, gaining patents, producing novels and plays, founding businesses or professional organizations (Torrance, 1981, 1988; Plucker, 1999), than were convergent tests of intelligence. The Alternative Uses task then represents a convenient paradigm for the study of creative processes and so this task has often been used in psychometric and experimental studies of creativity.

Although a number of convergent thinking tasks, such as Raven's Matrices, analogies and syllogisms, have been analyzed into component cognitive processes (e.g., Hunt, 1974;1999; Keane et al., 1994; Stenning and Oberlander, 1995), the Alternative Uses task does not appear to have been analyzed in this way and the experiments reported here aimed to remedy this deficit. Process analysis of complex cognitive tasks has typically involved use of think aloud methods (Ericsson & Simon, 1993; Gilhooly & Green, 1996; Green & Gilhooly, 1996). Such methods have been extensively applied in analyses of problem solving (e.g., Newell & Simon, 1972, on missionaries and cannibals, cryptarithmetic and chess; Gilhooly et al., 1999, on Tower of London) and in some studies of insight and functional fixity (Keane, 1989; Fleck & Weisberg, 2004) as sources of hypotheses and data regarding underlying processes. Experiment 1 in the present paper applied a think-aloud method, which has proven useful in other domains, to the Alternative Uses task with a view to identifying underlying processes and strategies in this creative thinking task.

As Ericsson and Simon (1993) argue, a task analysis is often a useful preliminary step and can suggest likely types of processes. In the Alternative Uses task it does seem *a priori* likely that some uses will be derived from searches of episodic memory for already known uses (some of which may be uncommon) and some will be derived from searches of semantic memory for object properties which can support different uses. This intuition is supported by the category generation studies of Vallee-Tourangeau, Anthony and Austin (1998) and Walker and Kintsch (1985). Vallee-Tourangeau et al.(1998) found in a study of strategies for generation of ad hoc categories (e.g., " things people take to a wedding") that such categories were most often initially generated by an *experiential* strategy, where memories of specific experiences were invoked and secondarily by a *semantic* strategy, in which abstract conceptual characteristics were used to generate exemplars. Similarly, in a study of strategies in retrieving taxonomic category instances (automobiles, soups and detergents) Walker and Kintsch (1985) found a high degree of usage of strategies that depended on personal episodic memory (77%) with the remaining strategies based on semantic knowledge. These previous studies suggest that we could expect to find episodic memory of previously known uses to be common and to be the basis of initial responses in the Alternative Uses task with semantically based uses occurring more rarely and later in the response sequence.

An important issue in the use of think aloud procedures is that, although such methods have been found informative in many domains, some studies have suggested that thinking aloud may alter the way in which tasks are processed. Ericsson and Simon (1993) on the basis of an extensive review of studies employing think aloud methods reported that when think aloud was concurrent with the task and was direct reporting of information in working memory, then think aloud was a non-reactive method. However, Schooler, Ohlsson and Brooks (1993) reported that thinking aloud with direct concurrent reporting had an interfering effect on performance on three insight problem solving tasks. This result is known as verbal overshadowing and although it has not been reliably replicated with insight tasks (Fleck & Weisberg, 2004), it is good practice in think aloud studies to include a control condition in which participants work silently in order to assess possible verbal overshadowing effects. Experiment 1, reported below, included a suitable control condition and tests for possible reactive effects of think aloud. Experiment 2, reported below, built on the strategy results of Experiment 1 and addressed the role of executive processes in the strategy based generation of responses which were self-classed as novel for the participant.

Experiment 1: A think aloud study of divergent thinking.

Method

Participants: 40 participants (32 female, 8 male) took part in the think aloud condition and a control group of 64 (51 female, 13 male) participants worked silently in a group setting. Both groups produced written responses. All participants were university students.

Procedure: The following instructions were given to both think aloud and control groups. "You will be asked to produce as many different uses as you can think of, which are different from the normal use, for a number of common objects. For example, the common use for a newspaper is for reading, but it could also be used for swatting flies, to line drawers, to make a paper hat and so on. You will have two minutes on each object. Its common use will be stated but you are to try to produce possible uses which are different from the normal one and different in kind from each other. Any questions?
I will tell you when to stop on each item. You will have two minutes for each item".

Participants were then presented with the names of 6 items, one at a time, for which they were to produce novel uses in writing. The items were brick, car tyre, barrel, pencil, shoe, and hanger. In each case the common use was given and other different uses were requested.

The think aloud group were also first given standard instructions adapted from Ericsson and Simon (1993), as follows.

"In this experiment we are interested in what you think about when you find solutions to some problems I am going to ask you to do. In order to do this, I am going to ask you to *think aloud* as you work on the problems you are given. What I mean by "think aloud" is that I want you to tell me everything you are thinking from the time you first see the question until you reach a solution or I tell you to stop working on the problem. I would like you to talk aloud constantly from the time I present each problem until you are asked to stop. I don't want you to plan out what you say or try to explain to me what you are saying. Just act as if you are alone in the room speaking to yourself. It is most important that you keep talking. If you are silent for any long period of time, I will ask you to talk. Please try to speak as clearly as possible as I will be recording you as you speak. Do you understand what I want you to do?

We will start with a practice problem to get you used to thinking aloud. While thinking aloud, tell me how many windows there are in your parents' house?"

After the think-aloud practice task, participants received the Alternative Uses task instructions and proceeded to carry out the Alternative Uses task while thinking aloud.

Results

In the results reported below, all confidence intervals and tests used $\alpha = .05$

Comparisons of think aloud and silent working conditions

Although thinking aloud is generally found not to affect performance in thinking tasks (Ericsson and Simon, 1993), in some cases interfering effects ("verbal overshadowing") have been reported (Schooler et al., 1993) and so it is customary to carry out checks on possible reactive effects of thinking aloud before analyzing the verbal protocols.

The total uses produced per participant over the 6 items for the Think aloud and Silent groups were very similar. The Think aloud mean (with 95% confidence interval) = 27.25 (+/- 3.14) uses, *SD* = 10.12; Silent mean = 26.43 (+/- 2.09) uses, *SD* = 8.26. Reported uses were rated on a 7 point scale for novelty (1 = not at all novel ; 7 = highly novel) by an independent judge. A second judge rated a random sample of 50 of the proposed uses and the two judges showed a satisfactory degree of inter-judge reliability (r =.85 +/- .08, df =48, p <.01). The average rated novelty of uses produced was similar for Think aloud and Silent conditions. The Think aloud mean novelty = 2.54 (+/- .12), *SD* = 0.74; Silent mean novelty = 2.45 (+/- .12), *SD* = 0.51. We also examined correlations between number of uses produced and average novelty for the think aloud and silent groups separately. These two measures are usually moderately correlated. The two correlations were very similar (for Silent group, r = .43 (+/- .10), df = 62, p <.01; for Think aloud group r = .49

(+/- .12), *df* =38, *p* < .01). These comparisons between the think aloud and silent working groups are re-assuring in that the results support the view that the think aloud requirement did not affect the normal flow of processing and that verbal overshadowing was not present.

Protocol analysis

The think aloud protocols were transcribed and segmented into short phrases as is standard in protocol analysis (Ericsson & Simon, 1993; Gilhooly & Green, 1996). An overall total of 2,343 segments were identified over the 40 participants' attempts at the 6 divergent items. The segments were classified into an initial set of 18 substantive categories which were taken to reflect different processes involved in carrying out the Alternative Uses task plus a residual "Other" category (which accounted for less than 1% of segments). The 15 categories which each accounted for more than 1 % of segments are listed in order of frequency below (with average % incidence per participant and 95% confidence interval), together with a brief characterization and example segment in each case. Also listed is the % of participants who had responses in each category; these figures indicate that none of the categories were solely due to a small minority of individual participants. The coding scheme was checked for reliability by having a sample of 100 segments coded by a second judge. Simple agreement was found for 84% of the segments and the Kappa statistic (Fleiss, 1981), which adjusts for chance levels of agreement, was 0.81. We concluded that the coding scheme was sufficiently reliable to proceed with further analysis.

Coding scheme

1. *Unmediated use* (33.3% +/- 3.3%): States possible use without explanation. E.g. "A tyre could be used as a floatation aid". Shown by 100% of participants.

2. *Item naming.* (11.66% +/- 1.5%): Repeats name of item. E.g. "Brick, brick, brick…"

Shown by 83% of participants.

3. *Episodic Memory use*. (9.2% +/- 1.7%): States possible use with reference to a specific memory. E.g. “I remember my father used a brick to stop a car rolling away.” Shown by 75% of participants.

4. *Use query.* (5.9% +/- 0.90%). Poses use problem. “Now what else could I use a shoe for?” Shown by 78% of participants.

5. *Dominant use*. (5.7% +/- 0.8%). States main use of object. E.g., “A pencil can be used to write things.” Shown by 85% of participants.

6. *Dissassembly uses*. (5.5% +/-1.3%). States a way of decomposing the target item and using the resulting components. E.g., “Remove laces from shoe and use them to tie your hair up.” Shown by 80% of participants.

7. *Repeat use.* (3.6% +/-0.7%). Repeats an already stated use for the target item. E.g., “A brick could used as a weapon… <possible intervening segments>……Use brick as a weapon.” Shown by 68% of participants.

8. *Property*. (3.4% +/- 0.7%). States property of object. E.g., “Bricks are heavy”. Shown by 55% of participants.

9. *General use* (3.5% +/- 0.8%). States very wide category of use. E.g., “A barrel could be used as part of a work of art”. Shown by 68% of participants.

10. *Impasse* (3.4% +/- 0.6%). Indicates participant cannot report any further uses at this point. E.g., “I can’t think of anything else to do with a pencil.” Shown by 68% of participants.

11. *Property Use*. (2.9% +/- 0.7%). Explicitly indicates property which enables the stated use. E.g., “A pencil is sharp so can be used to poke holes in paper.” Shown by 48% of participants.

12. *Example use*. (3.0% +/- 0.5%). After a General use, gives more specific examples. E.g., (After saying “A brick could be used in building things”), “A brick could be used for

building walls, paths, roads, channels for water.” Shown by 68% of participants.

13. *Imagery*. (3.0%, +/-1.2%). Indicates forming a mental image. E.g., “I am imagining a car tyre”. Shown by 40% of participants.

14. *Context*. (2.9%, +/- 1.2%). Mentions context in which target object often found. E.g., “You often see tyres in garages.” Shown by 40% of participants.

15. *Broad Use First* (2.9%, +/- 1.2%). Considers target object against an initially broad use category. E.g., “Could a barrel be used as a kind of transport? Yes, you could float things in it down a river.” Shown by 28% of participants.

To facilitate further analysis the above detailed codes were grouped into four larger strategy and two process categories.

The process categories were as follows:

1. **Memory use production.** Retrieval from memory of alternative uses, either unmediated, without mention of specific memories or mediated, with specific reference to prior knowledge acquired through direct or indirect experience. Unmediated uses are presumed to derive from knowledge held in long term memory and hence are grouped with uses deriving from episodic long term memory. Segments coded as *Unmediated* or *Memory based* are taken to indicate this strategy.
2. **Property use production**. Retrieving and scanning properties of the object and then using these properties as cues to retrieve uses which require those properties. Segments coded as *Property* or *Property based* are taken to indicate this strategy.
3. **Broad use based production**. Reviewing object against a number of broad uses , such as “Transport”, “Weapon”, “Aesthetic”, for possible

application. Segments coded as *General Use, Example Use, Broad use first*, are taken to indicate this strategy.

4. **Disassembly use production**. Imagining disassembling the object and using parts or recombining parts. This corresponds to the single code *Disassembly uses*.

Two broad types of processes were identified:

1. **Self-cueing.** Repeating object name, imaging object and recalling object contexts, apparently to cue relevant information. Segments coded as *Image*, *Object naming* and *Context* are taken as indicating this process.
2. **Intrusions.** Repeating already given uses for object or stating dominant use (against instructions). Segments coded as *Repeat* or *Dominant use* are taken as indicating this process.

Relating strategies and processes to performance measures

We examined whether frequencies of strategies and processes were linked to fluency and novelty of production as follows. The frequencies of the 4 main strategies and the 2 other processes were obtained by summing the respective segment level codes per participant. Average novelty per participant was obtained by rating each use produced on a 7 point scale of novelty (7 = highly novel) and averaging over uses for each participant. Distributional data are shown in Table 1. Those measures which were positively skewed (Property, Broad Use, Dissassembly and Intrusions) were satisfactorily corrected by square root transformations for subsequent analyses.

INSERT TABLE 1 ABOUT HERE.

Correlations were then obtained between the performance and strategy measures. These are given in Table 2.

INSERT TABLE 2 ABOUT HERE.

From the simple correlations it appears that fluency of performance in divergent thinking is mainly determined by frequency of the Memory strategy while novelty is more related to use of Disassembly and Broad Use strategies with a lesser contribution from Memory strategies. Given that there are correlations among the measures of strategy frequency, in order to clarify the interrelations between strategy, process and production measures further, we carried out simultaneous multiple regression analyses with number of written responses and average novelty as the dependent variables and the strategy and process variables as predictors.

The regression results were broadly consistent with the simple correlations and indicate that Disassembly strategy frequency made a strong independent contribution to novelty of uses when other factors are taken into account ($\beta = .57$, $t(34) = 4.60$, $p < .01$). Memory strategy frequency also made an independent contribution to predicting novelty ($\beta = .37$, $t(34) = 3.15$, $p < .01$). Broad use strategy did not make a substantial contribution to novelty when other variables were taken into account ($\beta = 0.16$, $t(34) = 1.25$, ns) suggesting that the significant simple correlation with number of uses was largely due to confounding with other more influential variables. Regarding fluency (i.e., number of uses produced), Memory strategy is the sole independent predictor when other variables are taken into account ($\beta = .73$, $t(34) = 6.71$, $p < .01$).

Order of occurrence of strategies

To check for differences in the typical order of occurrence of strategies, the first incidence of the indicators of each strategy was obtained for each of the 6 target items and averaged for each participant. Overall, Memory Strategy tended to appear first in the sequence of protocol segments at an average segment sequence position of 2.59 (+/- .40), while Disassembly, Broad Use and Property Strategies first appeared on average at positions 5.27 (+/- .75), 5.35 (+/- .60) and 6.06 (+/- 1.03) respectively. Thus, Memory Strategy tended to occur earlier than the others (indeed occurred first in 97.5% of rankings of order of occurrence for the 40 participants) but there was no strong difference between the later appearing strategies in terms of order of appearance.

Discussion

There was no evidence in this study to suggest that the think aloud procedure caused verbal overshadowing in the Alternative Uses task and the verbal protocols yielded readily interpretable results. Memory responses were frequent and tended to be produced early. Uses produced in this way were of uses pre-known to the individual and did not therefore involve any personal-psychological creativity (Boden, 2004). It seems that Memory responses would generally be produced first as these will tend to occur automatically and rapidly in response to the item cue. Other strategies are presumed to be more effortful and executively demanding and would be expected to occur later when the initial automatic retrievals have been exhausted. When Memory use production had exhausted readily retrieved instances of experienced alternative uses, most participants switched to the other strategies which could produce more novel uses. We now consider processes involved in the more demanding strategies in turn.

Property Use Production can be interpreted as involving (1) retrieval of one or more properties of the target object and (2) a search of semantic memory for uses or functions which have as a requirement the retrieved property or properties. Property Use Production could give rise to personally novel uses not previously thought of or experienced by the person (e.g., using a brick as a pillow on the basis of its size and shape). Theoretically, object properties may be retrieved from an amodal semantic representation or through an imagery process in which an image of the object is generated and examined for properties. Some 40% of our think aloud participants did speak at least once of “seeing” the objects while searching mentally for uses which strongly suggests some involvement of imagery. This is consistent with LeBoutillier & Marks’s (2003) finding in a meta-analytic study of 9 experiments with a total of 1494 participants of a relationship between imagery ability and creativity as indexed by divergent thinking tasks.

Disassembly as a strategy involved imagining the breaking up of the item into components (e.g., a shoe may be broken up into sole, upper and laces), each of which can then serve as “input” to Memory or Property Use Production. The Disassembly strategy was particularly associated with production of uses judged to be highly novel.

Broad Use Production was relatively infrequently observed and involved considering possible broad categories of use such as “means of transport” and determining whether the target object had properties permitting that broad use. The Broad Use Production strategy is similar to an approach found to be fruitful in Finke’s (1993) study of the Geneplore model of creativity in the creative synthesis task. In this task participants are requested to combine given shapes “to make interesting and potentially useful objects”. Finke found that if combinations were produced without a pre-set detailed goal and then interpreted as examples of many different broad categories, such as furniture, tools, toys and so on, overall creativity of the combinations was higher than when specific goals were preset. Similarly, in the Alternative Uses task the Broad Use strategy seeks to interpret target objects, such as a shoe, as possible examples of a range of broad uses such as means of transport, furniture, ornaments, foodstuff etc. By this means a shoe might be ascribed a possible transport use, e.g., a letter could be put in a shoe and then be transported by throwing the shoe over a high wall.

Overall, we found that episodic memory strategies predominated early in the process and were then followed by strategies which were based on more abstract semantic knowledge of properties of the target items. Vallee-Tourangeau et al., (1998) and Walker and Kintsch (1985) found similar patterns in studies of strategies in generation of ad hoc and taxonomic categories respectively, in that such categories were most often generated by an *experiential* strategy, where memories of specific experiences were invoked and secondarily by a *semantic* strategy, in which abstract conceptual characteristics were used to generate exemplars. Property, Broad Use and Disassembly strategies could be regarded as different semantic strategies. Memory strategies do not produce personally novel uses and are likely to be less executively demanding than the semantic strategies and so the next study addresses the relationship between executive functions and the personal novelty of uses produced.

Experiment 2: Executive Functions and Old v. New uses.

The results of Experiment 1 above suggested that participants engaged in a range of strategies when carrying out the Alternative Uses task. Use of strategies is usually accepted to involve a marked degree of executive control in various ways. Two generally acknowledged executive processes (Baddeley, 2003; Miyake, Friedman, Emerson, Witzki & Howerter, 2000) are *inhibition* and *switching*. In divergent production the dominant use of the object must be *inhibited*. Furthermore, the Memory strategy will require inhibition of earlier produced dominant memories as the process continues to produce responses. Furthermore, possible responses will have to be evaluated for suitability and unsuitable ones inhibited. A decision will have to be made as to when to *switch* from the Memory strategy to one of the other strategies. If the Property Use Production process is running, further decisions about switching from one property cue to another will be required, coupled with inhibition of previously used cues. Theoretically, deliberate switching of retrieval cues in this way is seen as a central executive function in working memory models (Baddeley and Logie, 1999; Engle, Tuholski, Laughlin & Conway, 1999) and so the central executive would be expected to be involved in divergent production of novel uses. Interestingly, the standard task used for loading the central executive (*random generation* of items from a set, such as digits 1-9) requires *novel* response sequences. Random generation requires constant switching of the bases for responses (i.e. flexibility), overcoming habits and breaking sets, as is the case with divergent production tasks. Thus, the notion that executive processes are involved in production of novel responses is intrinsic to the working memory model.

Empirical results also support the view that executive functions are involved in divergent production and so it would be expected that divergent production of new uses would be correlated with performance on other executively loading tasks such as letter fluency (Phillips, 1997). Martin, Wiggs, Lalonde and Mack (1994) found that a secondary executive loading task impaired performance on a letter fluency task (i.e., produce as many words beginning with specified letter as possible in a set time) more than on a category fluency task (i.e., produce as many examples as possible of a common taxonomic category). This is interesting because letter fluency is generally regarded as more dependent on flexible responding (an executive function) than is category fluency. Conversely, they found that secondary task with a low executive load interfered more with category fluency than with letter fluency. Category-fluency is regarded as more dependent on automatic spreading activation than is the letter fluency task. Elsinger and

Grattan (1993) found an impairment in frontal patients in Alternative Uses performance which again is consistent with executive involvement in divergent production, given the strong link between executive processes and frontal areas of the brain. Overall, there appears to be a good case that executive processes are involved strongly in divergent production.

The processes for carrying out the Alternative Uses task which have been proposed here indicate that Memory responses tend to occur first and so early responses will tend to be pre-known or "old" uses already stored in long term memory. Property-, Broad Use- and Disassembly uses tended to be produced later. This suggests that responses to the Alternative Uses task could be split into "old" (previously known, drawn from memory) and "new" (not previously known, generated during the task for the first time for the participants concerned.) Previous analyses of Alternative Uses response data have not separated these types of responses, but it may be important to do so because, on our analysis, "old" and "new" responses arise through different processes. A rather similar point was made on *a priori* grounds by Quellmalz (1985) in an evaluative review of the Alternate Uses Test in which he argued that :

" If Alternate Uses is proposed as a measure of creativity, it would be necessary to distinguish newly proposed uses from previously experienced uses, i.e., to disentangle background experience from creativity."

In line with Quellmalz's point and following from our analyses of Experiment 1, in Experiment 2 reported below, participants were asked to identify which of their responses to an Alternative Uses task were "old" and which were "new" to them and had been first thought of during the experiment. Since "new" uses, in our view, always arise from more executively involving processes we predicted that frequency of "new" uses would correlate with performance in a task, which also draws on executive processes *viz.*, the *letter fluency* task (Martin et al., 1994; Elsinger & Grattan, 1993). Conversely, we predicted that frequency of production of "old" uses deriving from the Memory strategy would correlate with performance on *category fluency*, since both of these are presumed to involve retrieval through relatively automatic processes such as spreading activation (Martin et al., 1994).

Method

Participants: 103 students from Brunel and Oxford Brookes Universities in England acted as participants (83 female, 20 male).

Procedure: Participants each carried out a single Alternative Uses divergent thinking task, under silent working conditions, for 2 minutes. 54 participants were tested with the item "Tyre" and 49 were tested with the item "Barrel". In both cases standard instructions were given, as in Experiment 1. Responses were written.

After completion of the divergent production phase, participants were asked to indicate by circling, for each use they had produced, which were first thought of while doing the task i.e., had never before seen or heard of before, either in their own experience or in films, books, television etc. Participants then carried out a category fluency task (name as many animals as possible) for 3 minutes and a letter fluency task (produce as many different examples as possible of words starting with "H") for 1 minute.

Results

Participants were able to follow the instruction to indicate "new" responses. Examples of "new" and "old" responses to the "Tyre" item are given below and appear to have considerable face validity.

"Old"	**"New"**
A swing	A measuring device
A crash barrier	A picture frame
A float	To hide things in
Part of assault course	As waist protection

To examine further the validity of the self defined division into "old" and "new" responses, 20 "old" and 20 "new" responses were rated for novelty on a 7 point scale (7 = highly novel) by an independent judge. The "old" and "new" responses were paired in that each pair of responses came from a particular different participant chosen at random. It was expected that self-defined "new" uses would also tend to be seen as more novel by other observers. "Old" uses received a mean novelty rating of 3.37 (+/- .51) and "new" uses had a mean novelty rating of 4.80 (+/- .61). This difference was highly significant, $t(19) = 3.49$, $p < .01$.

Our analysis suggests that "old" responses are produced through memory based responding and this occurs at an early stage while "new" responses arise through later occurring strategic processes. Thus, the average output position of "new" responses in the sequence of uses produced should be later than the average output position of "old" responses. As expected, the average output position (5.81 +/- .12, $SD = 1.23$) of the "new" uses produced in this study was significantly later than the average output position (3.48 +/- .09, $SD = 0.85$) of the "old" uses , $t(102) = 10.02$, $p < .001$.

Descriptive statistics for numbers of responses for "old", "new", category fluency and letter fluency are given in Table 3 for the groups responding to "Tyre" and "Barrel" target items separately. The two groups were similar on all measures as shown in Table 3 and so the groups' data were merged in the following analyses in order to clarify the patterns of results, which were similar in the unpooled data.

INSERT TABLE 3 ABOUT HERE

Correlations among the variables for the merged data of 103 participants are shown in Table 4.

INSERT TABLE 4 ABOUT HERE

As predicted on the basis of the analysis outlined here, the simple correlations indicate that “new” use production was more strongly linked to the executively loading task of letter fluency than to category fluency while “old” use production was more strongly related to category fluency, which is generally seen as being relatively more based on automatic spreading activation than to letter fluency. To clarify the interrelationships further, simultaneous multiple regressions were run for “new” and “old” uses as dependent variables and the fluency scores as predictors.

The regression results indicated clearly that fluency of production of “new” uses was predicted by letter fluency ($\beta = .34$, $t(101) = 3.25$, $p <.01$) but not by category fluency ($\beta= .05$, $t(101)= 0.49$, ns) and *vice versa* for “old” uses which were predicted by category fluency ($\beta = .29$, $t(101) = 2.72$, $p < .01$) but not by letter fluency ($\beta = -.17$, $t(101) =-1.57$. ns)

Discussion

This study examined the utility of a new method of scoring responses to the Alternative Uses task which involved having participants self categorise their responses as new to them or not, where “new” responses were those not previously experienced either directly or vicariously and first thought of during the task. Participants were able to follow the instructions and the self reported categorizations had face validity. The validity of the self categorization procedure was further supported in that “new” uses were rated by an independent judge as more novel than “old” uses. Self categorized “new” responses occurred later in the output series than “old” responses. A further result of this study is that production of personally judged “new” uses is related to ability to carry out a different executively loading task, viz., letter fluency, while production of “old” responses was not linked to letter fluency. This is supportive of the present analysis which posits executively loading strategies as underlying “new” use production. Our interpretation of this result is that participants with greater executive capacity were better able to carry out demanding strategies in both letter fluency and alternative uses, hence the observed correlation. On the other hand, production of personally judged “old” uses was more associated with performance of a task (taxonomic category fluency) which reflects largely automatic retrieval processes (although executive capacity would also have some role). This is also consistent with the view of the present analysis that “old” responses are mainly due to automatic retrieval of uses from long term memory. However, it is acknowledged that executive processes may also be involved in taxonomic category fluency; for example, in generating animal names it can be useful to switch the basis of search from domestic to wild animals and so on. Part of the correlation between category fluency and letter fluency may well reflect this overlap in type of resources employed in the two tasks. Our interpretation here is on the basis that letter fluency is more demanding of executive capacity than is taxonomic category fluency rather than that taxonomic category fluency does not involve executive capacity at all. Finally, it may be noted that the differential links of letter fluency to new uses and category fluency to old uses emerged most clearly from simultaneous regression analyses which took account of possible confounding and suppression effects among the variables.

General discussion

The work reported here aimed to cast light on the processes underlying performance in the Alternative Uses divergent thinking task. Although divergent thinking is important in creative thinking, insight problem solving and overcoming functional fixity, analyses of the cognitive processes involved in divergent thinking did not appear to have been carried out before. On the basis of the think aloud study reported in Experiment 1, we identified four main strategies: Memory, Property, Broad Use and Dissassembly strategies. Initial responses are based on a Memory strategy of retrieval from long term memory of pre-known uses. This is seen as a relatively automatic process of retrieving uses associated in past experience with the target objects. The Memory strategy was associated strongly with fluency of use production and made an independent contribution to average novelty of production (as rated by an independent judge). Thus extensive use of the Memory strategy can generate unusual uses which have been experienced by relatively few people but such uses are not truly cases of personal-psychological creativity in Boden's terms (2004, p.4). It is noteworthy that the first responses tend to be based on contextualized personal experience stored as episodic or more generalized autobiographical memories. This type of retrieval appears to be relatively automatic, rapid, and not heavily loading of executive capacity. Later responses tend to be based on slower, more effortful, and executively loading strategies. The general pattern of episodic, contextualised retrieval strategies followed by more semantically based strategies was also found by Vallee-Tourangeau et al. (1998) and Walker and Kintsch (1985) in studies of ad hoc and taxonomic category generation respectively.

Following Experiment 1 we suggested that subjectively old or pre-known responses could be distinguished from subjectively new responses which are generated for the first time during the experiment. In terms of Barsalou's (1983, 1991) approach to conceptual knowledge and processing, producing new uses for a familiar object is equivalent to cross-classifying the object into new ad hoc use categories. For example a wooden chair (probably initially categorized only as a member of the category "things which one can sit on") could be cross-classified as a member of many other categories such as "things that could be used as emergency firewood", "things that can be stood on", "things that could hold doors open" and so on. Such cross-classifications generally arise only in the context of specific goals and Barsalou (1983) suggested that automatic elicitation of many cross-classifications in the absence of relevant goals would normally be undesirable and highly distracting as objects can be cross-classified in an indefinite number of ways. The Alternative Uses task is a special situation in which the person is actually given the unusual goal of producing as many cross-classifications as possible. Barsalou (1983) found that cross-classifying objects into new ad hoc categories was facilitated by provision of goals. The Broad Use strategy may work in a similar fashion by self-generating possible goals (e.g., "Use as transport") which then facilitate cross-classifying the target items as objects that can meet the self-generated possible goals (e.g. , to meet the "Use as transport" goal, "use shoe as means of transporting small objects while walking").

The second experiment examined the role of executive capacity in generating new and old use responses. Ability to produce "old" responses, presumed to be derived from memory of pre-known uses, was associated with ability to retrieve items from a well known taxonomic category. It may be suggested that in both cases memory based strategies underlie performance and involve low executive loads. Participants characterized by less executive capacity then find it harder in divergent production to switch to other strategies and to resist intrusions of previous uses. Participants who had greater executive capacity as indicated by higher response scores on the letter fluency task produced more "new" responses in divergent production. This association of divergent production with executive functioning suggests further studies which more explicitly test differences in particular executive functions such as switching and inhibition in relation to Alternative Uses performance.

Other fruitful lines for future research would include examining effects of different modes of item presentation such as pictures or actual objects as against object names. Different modes of presentation would be expected to make different properties salient which in turn should affect new uses produced through the Property strategy. Also, mental workload might be reduced by picture or object presentations since properties would be generally more readily accessible. Such stimulus support would be expected to yield more responses than found with standard verbal label presentation, as well as leading to different properties being used as bases for responding. The separate measurement of "new" and "old" responses for individuals suggests possibilities for future psychometric research. It would be expected that the "new" responses measure would be a more valid predictor of real life creativity than total responses (which mixes "old" and "new" together). Work is required to explore further the reliability and general validity of the "new" response measure in the Alternative Uses task.

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Table 1. Number and novelty (rated on 7 point scale, 7 = high) of written uses produced and frequencies of main strategies and processes. Descriptive statistics. N = 40.

	Mean	95% CI	SD	Skew
Production measures				
Written Uses	27.28	+/- 3.13	10.12	-.01
Average novelty	2.54	+/-.23	.74	.37
Strategies				
Memory	23.47	+/-2.67	8.60	.81
Property	4.05	+/-1.87	6.04	2.93
Broad use	4.72	+/-1.67	5.37	1.66
Disassembly	3.27	+/-1.45	4.67	4.05
Processes				
Self cueing	14.00	+/-2.90	9.37	.63
Intrusions	6.02	+/-1.78	5.74	1.65

Table 2. Pearson correlations between strategy, process and production measures. N = 40.

	1.	2.	3.	4.	5.	6.	7.	8.
1.Written Uses	1.00	.50**	.73**	.11	.09	.23	-.11	.20
2. Average novelty		1.00	.33*	.12	.42**	.62**	-.20	-.14
3. Memory			1.00	-.06	.01	-.04	-.14	.08
4. Property				1.00	.18	.20	.19	.38*
5. Broad use					1.00	.38*	-.19	-.16
6. Disassembly						1.00	-.04	.02
7. Self cueing							1.00	.47**
8. Intrusions								1.00

** = $p < .01$, * = $p < .05$. 2 tail tests.

Table 3: Descriptive statistics . Numbers of "Old" and "New" alternative uses for "Tyre" (N= 54) and "Barrel" (N=49). Numbers of items produced in Category Fluency (Cat. Flu.) and Letter Fluency (Let.Flu) tasks.

	"Tyre" group			"Barrel" group		
	Mean	CI	SD	Mean	CI	SD
"Old"	3.93	+/-.72	2.68	4.18	+/-.69	2.45
"New"	2.83	+/-.67	2.53	3.43	+/-.78	2.77
Cat. Flu.	33.74	+/-2.64	9.89	34.59	+/-1.08	8.22
Let. Flu.	13.39	+/-1.17	4.39	14.83	+/-1.13	4.02

Table 5: Pearson correlations among numbers of "Old" and "New" uses produced and numbers of items produced in Category Fluency and letter Fluency tasks. N= 103.

Variable	1.	2.	3.	4.
1. "Old"	1.0	-.27**	.22*	-.04
2. "New"		1.0	.20*	.36**
3. Category Fluency.			1.0	.44**
4. Letter Fluency				1.0

p < .05. ** *p* < .01