Sleep and creative problem-solving

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ABSTRACT

Anecdotal evidence suggests that sleep can aid in creative performance, but few studies have systematically investigated this association. Prior research suggests that creative thinking, particularly divergent cognition, is similar to mental states found in sleep and dreaming, especially during REM sleep. Studies have found that sleep benefits general learning and problem-solving, and facilitates insight that promotes enhanced performance on cognitive tasks. I investigated the effects of sleep on performance with a verbal task that explicitly requires creative ability. I hypothesised that participants with a period of sleep between task preparation and execution would perform better than participants with an equal period of daytime wakefulness. The study was a 2-level, single-factor design, with state of consciousness as the manipulated variable. Participants (n = 24) were recruited from the university undergraduates population. Participants memorised a wordlist for task preparation and then, after an interval of sleep or waking activity, used the same wordlist to write a creative short story for task execution. The stories were assessed for creativity-related constructs of fluency, flexibility and originality as measures of task performance. Participants' scores on the Creative Achievement Questionnaire (CAQ) and the Shipley Institute of Living Scale (SILS) were used to control for general creative ability and IQ respectively. ANCOVA results did not reveal significant differences between the groups in terms of creative performance, although some significant sex differences were found. Reasons for the obtained results are discussed and improvements to the study are proposed.

Keywords: Creativity; Divergent thinking; Sleep; Insight; REM; Dreaming; Incubation

There are many stories about people who gained creative inspiration from their dreams. Robert Louis Stevenson based his novel *Treasure Island* on a series of dreams. After years of work, Dmitry Medelyev developed the structure of the period table of elements from a dream (Stickgold & Walker, 2003). Such anecdotes are easy to find, and although general creative thinking has been studied extensively over the last 50 years, there is a scarcity of systematic investigations into the association between creativity and sleep.

Some studies have used self-report measures to investigate the past impact of dreams on waking life (e.g. Shredl & Erlacher, 2007; Pagel & Kwiatkowski, 2003) and found that participants reported a significant effect of dreams in domains such as creative work and general problem-solving. Of course, there are problems with this methodological approach. Participants may have attributed too much influence to the dreams, because of a personal bias, or may not have recalled the dream and the subsequent events correctly. Furthermore, the self-report research tends to focus on past applications of dream content on waking life, instead of studying the problem-solving or creative process as it occurred, under controlled conditions. The creativeness of the participants' dreams and the effect on their waking activities was often simplistically measured, using vague and inconsistent definitions of creativity.

Creativity itself is a notoriously difficult construct to study scientifically, not least because it is difficult to define precisely. This study used, at least initially, the following broad definition of creativity: cognitive processes based on intuitive and non-rational approaches that produce unconventional or novel results (Brophy, 2000; Christensen & Shunn, 2005; Stickgold & Walker, 2003). I aimed to investigate the role that sleep and dreaming can play in creative problem-solving, using an empirical approach.

PRIOR RESEARCH INTO CREATIVE PROBLEM-SOLVING

With respect to creative problem-solving, researchers make a conventional distinction between *divergent* and *convergent* thinking. Divergent thinking usually predominates in the early stages of problem-solving, when individuals generate ideas as possible solutions for the task (Vincent, Decker, & Mumford, 2002). In contrast, convergent thinking occurs more in

later stages of problem-solving, when individuals evaluate multiple possibilities and select the best solutions (Brophy, 2000).

In an attempt to describe the relationship between personality traits and convergent or divergent thinking, Brophy (2000) conducted research with university students given the task of developing new ways to market their university and improve its operation. The study found that most people were inclined to either divergent or convergent thinking, rather than an equal combination of the two processes. Divergent thinking was associated with personality traits such as autonomy, as well as complex symbol use and fantasy play. Furthermore, divergent thinking was predicted by a preference for ideation over evaluation, innovation over adaptation, and intuition over reasoning, as well as ambiguity tolerance, extraversion and an internal locus of control.

In contrast, convergent thinking was best predicted by a preference for reasoning, as well as for evaluation, adaptation, ambiguity intolerance, introversion and an external locus of control. In summary, the research demonstrated that divergent and convergent thinking are empirically distinct cognitive processes and illustrated some personality factors that influence preference for either cognitive style.

Most research in creativity has focused on factors that influence divergent thinking. Priming for abstract thought, for instance, has been found to enhance divergent thinking. Forster, Friedman, and Liberman (2004) tested problem-solving ability with reference to construal theory, which suggests that individuals perceive distant future events in more abstract terms than near future events, which are perceived more concretely. The researchers asked the participants to imagine a scenario occurring on either the next day or in the next year. Immediately afterwards, they completed a problem-solving task using an unrelated scenario set in present time. The authors found that when cognitive processing was primed for abstract, imaginative thought, participants performed better on a divergent task (e.g., generating solutions for an interior decorator), but performance on a convergent task was impaired (e.g., finding the best method for watering plants). The “next year” group also performed better on a visual insight task than the “next day” group, suggesting that the cognitive shift effect occurs across different creative modalities.

Most studies in this research domain have also focused on verbal tasks. For instance, Fink and Neubauer (2006) tested performance on verbal creativity tasks while measuring EEG alpha waves in participants. They found that divergent thinking in the tasks was associated with lower cortical arousal, diffused cortical activation and alpha synchronisation. Activity in the posterior parietal lobes was also associated with divergent thinking. In contrast, convergent thinking in the tasks was associated with higher levels of cortical arousal, alpha wave desynchronisation and more specific cortical activation, mainly in the frontal regions of the brain. The authors suggest that synchronisation in cortical activities indicates lowered cortical arousal, a resting phase for that region and possibly more efficient processing.

Fink and Neubauer (2006) also suggest that creative people are more capable of entering "primary" modes of cognition, such as dreaming, trance states and defocused attention, where ideation predominates over idea discrimination or cognitive inhibition. In this mental state, one would expect individuals to generate potential solutions effectively for a presented problem, but show impaired judgement when selecting the most appropriate solution to use. Primary cognition, therefore, appears to be theoretically similar to divergent thinking. Studies on systematic-relaxation techniques such as autogenic training, show that a relaxed state of mind has a short-term benefit for divergent thinking in verbal tasks, as well as convergent thinking to a lesser extent (Krampen, 1997). Again, this suggests that states of consciousness that differ from normal waking life can have a positive effect on creative problem-solving.

Danko, Starchenko and Bechtereva (2003) also investigated EEG cortical activity of subjects who were engaged in a creative verbal task. They found an increase in localised synchronisation for low frequency waves in the anterotemporal areas of the brain, indicating, according to their interpretation, increased activity in those regions. Diminished spatial synchronisation was found in the frontal and prefrontal regions of the brain, particularly in the midline area and left hemisphere, indicating lowered activity. The results from these studies raise the possibility that frontal brain regions need to be inhibited for divergent thinking to occur.

Peigneux et al. (2006) compared brain activity in waking and sleeping states with regard to general task performance. Participants trained in a virtual environment-based spatial task and had opportunities for practice, before a 3.5 hour interval of either sleep or wakefulness and then retesting on the task. fMRI scans showed similar patterns of brain activity for both

groups at each phase of the study, despite the different states of consciousness in the interval period. This pattern of data suggests that whatever consolidation of learning occurs in sleep also occurs, to a certain extent, during periods of wakefulness. Importantly, however, the results showed a greater improvement in task performance on retesting with the sleep group than with the waking group. This suggests that memory consolidation is more effective during sleep.

SLEEP, DREAMING, MEMORY AND CREATIVITY

Many studies show the importance of sleep for long-term memory consolidation. This association could be especially relevant for creative problem-solving, as subjects draw on episodic and semantic (i.e. long-term, declarative) memories for problem-solving (Vincent et al., 2002). Episodic memories concern the individual's personal experiences, whereas semantic memories are facts and ideas abstracted from personal experience and learning. In a neuropsychological investigation of the relationship between sleep and memory, Plihal and Born (1999) identified the hippocampus, a brain region closely associated with learning and the formation of new memories (Squire, 1992), as essential for the consolidation of declarative memories during sleep. The authors also found that the pituitary-adrenal system, associated with cortisol secretion and stress responses, was inhibited in early stages of nocturnal sleep. The hippocampus and related structures in the limbic system have numerous cortisol receptors, suggesting that elevated levels of cortisol secretion could affect memory consolidation. The researchers found that subjects receiving a cortisol infusion performed worse than controls on a paired-associate word task. No significant differences were found when the task required visual skill, suggesting that the cortisol effect applies mainly to verbal declarative memory consolidation. Therefore, the fact that cortisol secretion is inhibited to a large extent during early sleep may suggest that early sleep plays an important role in the consolidation of verbal declarative memory.

Káli and Dayan (2004) argue for a theory that during sleep, the hippocampus replays activation of recent memories for encoding episodic memory in the neocortex. The authors also found that lesions in hippocampal structures impair semantic memory consolidation. They explain the overlap between memory systems by suggesting that the hippocampus affects semantic memory consolidation by the storage and retrieval of relevant examples in

episodic memory. In other words, abstract, factual information might be more memorable if the individual concerned can relate it to personal experience. Similarly, Cipolli, Bolzani, Tuozzi, and Fagioli (2001) suggest that dream rehearsal consolidates declarative memory during sleep. Furthermore, an increase in hippocampal activity is associated with REM sleep, when most vivid dreaming normally occurs (Nielsen & Stenstrom, 2004).

Nielsen, Kuiken, Alain, Stenstrom, and Powell (2004) found that episodic memory in dream content usually originates from the preceding day. A delayed inclusion effect was also found, however, with episodes dated approximately 7 days prior included in the dream content. Importantly, the delayed inclusion memories were usually associated with personal relationships, positive emotions and resolved problems, whereas the residual, previous-day memories were sometimes associated with pressing issues, problems and unresolved tasks.

Cipolli et al. (2001) found more evidence for the inclusion of recent episodic memories with a task where subjects had to memorise nonsense sentences shortly before entering sleep and were requested to recall the sentences after waking the next morning. Linguistic analysis of recorded dream content showed that the words from the sentences and close synonyms appeared in the subjects' dreams at above chance levels. The researchers showed that cognitive concern with ideas or memories increased the likelihood of the relevant items appearing in dream content. The context and arrangement of the elements did not follow the sentence structures, however, as the dream narratives did not resemble the narratives suggested by the sentences. Consequently, the researchers suggest that cognitive concern operates at a low level, or initial stage, of dream generation, by influencing the semantic and episodic memories accessed during sleep. These studies also suggest that dreams could aid creative problem-solving by restructuring the episodic memories - and associated semantic memories - of the problem during the memory consolidation process that occurs during sleep. Further research is needed to establish how much of this process is experienced as dreams and remembered upon waking. Alternatively, to what extent does this restructuring process occur without any awareness, as is found in insight and incubation?

Insight and *incubation* are also believed to be important processes in creative problem-solving. Incubation is conventionally theorised as a process where subjects set aside an unsolved problem that they later spontaneously solve, either by unconscious ideation or by cues from environmental stimuli (Christensen & Schunn, 2005). Insight is defined as

cognitive restructuring that leads to a sudden gain in knowledge (Wagner, Gais, Haider, Verleger, & Born, 2004). Christensen and Schunn (2005) found that participants who were informed of the existence of alternative strategies and relationships between problems were more successful at problem-solving and gaining insight, presumably by incubation. The authors gave puzzles to test subjects to solve, some of which used related principles. They found that participants could solve previously "difficult" puzzles when presented later in the session with similar puzzles that cued the correct solution. It appeared that an *interactive incubation* occurred, which is insight later gained from external stimuli that suggested new associations. This is in contrast to what the authors term *autonomous incubation*, where subjects would have developed new ideas unconsciously. It is most likely that interactive incubation predominated because the puzzles were administered in a continuous fashion, requiring prolonged conscious focus. No opportunity was presented for significant unconscious processing, as might occur in sleep, for example.

REM sleep appears to promote insight based problem-solving more than non-REM sleep (Stickgold & Walker, 2004). Wagner et al. (2004) trained participants in a number processing task based on logical rules. After a period of sleep, sleep deprivation or daytime wakefulness, the participants were retested on the task. The researchers found that all participants gradually improved task completion speed with practice, but the sleep group participants improved considerably faster. A short-cut technique was also built into the task. Significantly more sleep-group participants than control-group participants discovered the short-cut. The sleep deprivation participants did not differ significantly from the daytime wakefulness participants, suggesting that time of day or tiredness were not confounding factors. Importantly, Wagner et al. (2004) did not inform the participants of the short-cut strategy; therefore they were not cued to find the alternative strategy before sleep, and, therefore, incubation did not occur in the task.

INDIVIDUAL DIFFERENCES IN CREATIVE ABILITY

Vincent et al. (2002) investigated the relationships between intelligence, expertise and creative ability in a group of US Army officers. The researchers presented the participants with hypothetical military scenarios that required them to produce solutions, which independently assessors rated for quality and originality. The authors found a strong positive relationship between intelligence and divergent thinking. Divergent processing was shown to

cause ideation, but not, however, shown to cause the application of those new ideas. The research also suggested that expertise provided knowledge needed for idea generation. This knowledge is stored as a combination of episodic and semantic memory, which again suggests that processes of encoding, consolidation and retrieval of declarative memory could have important implications for creative problem-solving.

Mood is also a potential factor in creativity. Kaufmann and Vosburg (2002) used film clips to induce positive or negative emotions in participants, or left mood un-manipulated in a control group. Solution-finding tasks that required divergent processing (e.g., suggesting all possible uses for a shoe) were then presented to the participants. The authors found that the positive mood group performed better (i.e., produced a greater quantity of answers) on the tasks than the other groups. Yet the positive mood effect had a "burst" characteristic, with a steep reduction in ideation as time passed, compared to the negative mood group and control. The authors suggested that positive mood promotes ideation at the expense of discrimination. Importantly, they acknowledged that the positive mood effect might have been stronger in this study because the experimental tasks specifically required divergent processing. Other studies have found no mood effect on creativity (see, e.g., Forster et al., 2004).

Small sex differences have been found with respect to creative thinking. Fink and Neubauer (2006) found greater increases in alpha wave activity in high verbal IQ females compared to average verbal IQ females when completing a verbal creativity task. The opposite phenomenon occurred with male subjects. The authors also found higher alpha-wave power in the right hemisphere in males and higher alpha-wave power in the posterior regions in females. No significant differences were found for the quantity of ideas generated. These results suggest that the task was processed differently according to sex, although the final result was similar. Clearly, more research is required to understand the implications of sex differences in creative problem-solving.

SPECIFIC OBJECTIVES AND HYPOTHESES

The research reviewed above generally suggests that sleep and dreaming is conducive to creative problem-solving. Creative thinking, especially divergent processing, has been associated with certain patterns of brain activity (most consistently frontal and left hemisphere inhibition and diffused cortical activity) that are similar to brain activity in

dreaming. At a cognitive level, creative thought is also associated with relaxed, defocused attention, fantasising, and predominantly abstract, as opposed to mundane, thinking. These cognitive qualities are also similar to the dreaming experience. Divergent thinking also requires episodic and semantic memories as a source for ideation. Research shows that declarative memory, especially episodic memory, is replayed and consolidated during sleep. Furthermore, cognitive concerns from the previous day are known to reappear in dreams, supporting the idea that problem-solving can occur during sleep.

More empirical research is required, however, that investigates the relationship between sleep and creativity. The scarcity of research in the literature regarding sleep and creative problem-solving performance means that there is little direct evidence for a causal effect. The amount of indirect evidence available, however, at least suggests the possibility of a relationship that is worth further investigation. The results of Wagner et al. (2004) suggest a causal relationship between sleep and insight that enhances task performance; Peigneux et al (2006) found that sleep improves general cognitive task performance. For both of these studies, however, a learned procedure was the main criterion for successfully completing the tasks. Further research is required to assess the benefits of sleep for performance on tasks that explicitly demand creative thinking. I propose the following hypothesis: participants who receive a normal period of sleep between preparation and execution of a verbal creativity task will perform significantly better than participants with an interval of normal waking activity between preparation and execution.

METHOD

Design

The study was a 2-level, single-factor experimental design with state of consciousness as the manipulated variable. The experimental group (SLEEP) had a period of sleep during the experiment, while the control group (WAKE) had a roughly equivalent period of waking activity. Creativity, especially divergent thinking, was measured in terms of fluency (number of responses), originality (infrequency of particular responses in entire sample) and flexibility (number of response categories and shifts between categories) (Carson et al., 2005).The dependent variable, performance on the creative task, was thus operationalised as three separate measures: Fluency, Flexibility and Originality.

Participants

I recruited twenty-four adult (18-26 years) participants from the undergraduate population at the University of Cape Town. Males and females were distributed equally between groups to control for potential sex differences in creative aptitude. All aspects of the experiment were conducted in English. This was not anticipated to affect the results significantly , as UCT is an English language institution with at least basic English proficiency as one of the entrance requirements. Scores on a verbal intelligence test also controlled for variations in language competence.

Instruments

The Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgens, 2005) was used to establish the participants' baseline creative ability (see Appendix A). This scale is a self-report measure that assesses prior achievements in 10 established domains of creativity: visual arts, music, dance, drama, architecture, humour, scientific discovery, invention and culinary. The CAQ has demonstrated test-retest reliability ($r = .81$, $p < .0001$) and internal consistency ($\alpha = .96$). The measure also has convergent validity with other measures of creative ability, as well as discriminant validity with IQ. The CAQ is also resistant to self-serving bias (Carson et al., 2005).

Considering that intelligence has been partially associated with creative ability (Vincent et al., 2002), the Shipley Institute of Living Scale (SILS; Shipley, 1940) was used to estimate the participants' Verbal IQ levels to control for the effect of prior English language competence (see Appendix B). The Shipley scale consists of two parts. Part 1 tests vocabulary by asking respondents to select the correct synonyms for target words. Part 2 tests pattern completion, where respondents fill in the correct letters or numbers to complete various sequences. The raw scores from this test were used, as the sample was homogenous enough in terms of age not to require standardised scores. The SILS has demonstrated its value in providing a quick and reliable estimate of IQ normally obtained from a Weschler intelligence test, with correlations ranging between $r = .73$ to .90 (Zachary, Crumpton, & Spiegel, 1985)

The primary experimental task used an edited word list (see Appendix C) drawn from lists used to test memory and recognition in clinical neuropsychology (Crawford, Steward, &

Moore, 1989). The participants memorised the word list and later used it to write a creative short story. The list consists of 24 common nouns, mostly concrete and imagery-rich to facilitate retention. The authors have also established semantic connections between some words on the complete list, which was used to ensure the edited list contained 12 semantically-related word pairs.

For the experimental SLEEP group, a polysomnograph monitored the participants' neural activity while asleep. Nine electrodes were attached to the scalp for the electroencephalograph to detect REM-typical brain waves. Six electrodes were attached to the face to record eye movements (electro-oculargraph) and muscle tone (electro-myograph), while two electrodes were attached to the chest to record the participants' heart rate (electrocardiograph). These instruments were used to detect periods of REM sleep. I recorded the sleep data for analysis in future studies.

Procedure

I conducted the study at Vincent Pallotti Hospital's Sleep Clinic (SLEEP Group) and at the ACSENT laboratory in the Department of Psychology at UCT (WAKE Group). The procedure comprised an experimental Session 1, Interval Period and experimental Session 2. At the beginning of Session 1, participants were briefed on all necessary details and received general instructions, after which they signed a consent form to confirm participation.

For the SLEEP Group, Session 1 occurred in the evening, when participants arrived at the clinic at 8pm. In contrast, the WAKE Group performed Session 1 during the mid-morning at 9am. Both groups had an interval between the end of Session 1 and the beginning of Session 2, but whereas the SLEEP Group spent that period asleep in the laboratory, participants in the WAKE Group completed their normal daytime activities.

During experimental Session 1, the SLEEP and WAKE groups were administered the CAQ and the SILS. After these tasks, the SLEEP Group participants prepared for sleep, before the electrodes were attached to them. The electrodes were attached between tasks to give the participants adequate time to habituate themselves to the potentially uncomfortable equipment before sleep onset. For the final Session 1 task, both groups received the word list and were instructed to spend 15 minutes memorising it, for an unspecified task at the next session. To help them remember the list, they had to write an example sentence for each

word, thus priming them for the writing task they would later complete and also promoting autonomous incubation during the interval.

Session 1 was structured to ensure that the memorisation period ended as close as possible to sleep-onset for the SLEEP group and as close as possible to departure from the laboratory for the WAKE group. Participants in the latter group were instructed to remain awake during the interval between sessions and not to write down any of the words from the list.

Session 2 occurred in the morning after awakening for the SLEEP group, 8 hours from sleep onset, and in the afternoon for the WAKE group at 4pm. Although the interval was slightly shorter for the WAKE group (6 hours vs. 8 hours), this difference was not considered significant enough to introduce a confounding effect in the study. To ensure that the SLEEP Group participants had time to fully regain consciousness before completing the tasks, the electrodes were removed after they awoke and the participants were offered tea, coffee or hot chocolate and an opportunity to refresh themselves.

In Session 2, all participants were first asked to write down as many list-words as they could remember. Next, they received the same word list from Session 1 and were instructed to write a short story using as many words from the list as possible. Participants were also encouraged to write as creatively as possible. Participants were given half an hour for the task, but were allowed to finish earlier if they wished. Afterwards, they were debriefed and compensated for their travelling expenses.

Data Analysis

The number of list-words the participants recalled and mis-recalled was counted, as well as the word count for each story. Stories were assessed using content analysis. The analysis utilised Carson et al's (2005) basic framework, with a scoring system specially devised for this study (see Appendix D for a worked example). For Fluency, the number of different words used from the list was counted, as well as the frequency of each word. The two scores were integrated by dividing the total frequency of list-words by the number of list-words used, creating a rate of instances per list-word.

For Originality, the number of unique non-list words was counted for each story, thus assessing the new ideas the participant added to the task. Only common nouns, plurals of

common nouns and noun modifiers, such as *report* card, were counted. Close synonyms of list-words, such as *home* for *house,* were not included.

For Flexibility, the number of pairs of unconventional semantic associations was counted. These were identified by analysing the narrative connections between the list-words. Legitimate pairs were counted where list-words were connected spatially, temporally or causally in the narrative. A higher frequency of unconventional rather than conventional associations is assumed to reflect greater creative processing in the task. At the data analysis stage, certain word-pairs (*house/garden* and *house/window*) were also recategorised as conventional semantic associations and were therefore not counted for Flexibility[1].

RESULTS

The valid sample size was $n = 12$ for both the WAKE group and the SLEEP group in all the analyses and a p-value of less than .05 was taken as α in all cases. I first created a correlation matrix was to investigate which covariates were most significant for the dependent variable scores. Significant ($p < .05$) correlations were found between Originality and SILS ($r = .56$), Originality and Word Count ($r = .59$), Fluency and Word Count ($r = .56$), and Flexibility and Recall ($r = .42$). CAQ scores did not significantly correlate with any of the dependent variable measures, although there was a significant correlation between the CAQ and SILS ($r = .45$). In fact, the CAQ was negatively correlated with both Fluency ($r = -.11$) and Flexibility ($r = -.26$), and was only a weakly positively correlated for Originality ($r = .15$). An Analysis of Covariance (ANCOVA) was conducted for each of the dependent variables, using the relevant significant covariates.

Fluency

Levene's test for homogeneity of variance gave a significant result ($p = .001$) for Flexibility, suggesting that the group variance for this variable may not be sufficiently homogenous for an ANCOVA to be successful. While ANCOVA is robust to violations of this assumption, the results may need to be treated with caution. A non-significant result for word count was found ($p = .273$), indicating that the variance was homogenous. Inspecting the probability plots for the variables (See Figures 1 and 2) do not reveal any significant deviations from expected normal values, suggesting that the data is normally distributed. The data were also

collected from independent observations. Thus, the data broadly fulfils the requirements for ANCOVA.

Although a significant difference in word count means was found between the groups (WAKE *M* = 333.5 vs. SLEEP *M* = 319.9), no significant difference was found between the groups for Fluency (see Table 1). The WAKE group had a marginally higher fluency score than the SLEEP group, but this was not significant (see Table 2). After controlling for word count, the difference was minimised further.

Flexibility

Levene's test for the Flexibility and Recall scores gave non-significant results (p = .704; p = .628), indicating that the variances were homogenous for these variables. Inspection of the probability plots (see Figure 3 and 4) shows no significant deviations from expected normal values, therefore the data are normally distributed. These data are taken from independent observations. Therefore the data meets the assumptions for ANCOVA

Although the groups were significantly different in terms of their recall scores (WAKE *M* = 20.33 vs. SLEEP *M* = 19.17), no significant difference was found between the groups for Flexibility (Table 4). The SLEEP Group participants did use more unconventional semantic associations with the list-words than the WAKE Group participants, but this difference was marginal (Table 5). Interestingly, after controlling for recall, the group difference for Flexibility increased slightly. This suggests that the participant's ability to remember the words at the next session had a small effect on how they used the words in the writing task.

Originality

Levene's test for the SILS and Originality scores gave non-significant results (p = .387; p = .311), indicating that the variances were homogenous. Inspection of the probability plots for these variables (See Figures 1, 5 and 6) show no significant deviations from expected normal values. Furthermore, the data were taken from independent observations. Therefore, this data meets the assumptions for ANCOVA.

Although the WAKE Group had a higher mean Shipley score than the SLEEP Group (*M* = 47.33 vs. *M* = 46.26), the difference between word counts became non-significant when the SILS score was taken into account (Table 6). The SLEEP Group had a slightly higher

Originality score (Table 7), which was increased after adjusting for covariates, but this difference still failed to reach significance.

A few other statistical analyses were conducted with the data to investigate differences that were not addressed by the experimental hypothesis. Participant age did not significantly correlate with any of the other variables. A significant correlation was found for Fluency and Flexibility (r = .51). Analyses of covariance were also conducted using participant Sex as the independent predictor. No significant differences were found between the dependent variables, except for Originality.

Effect of Participant Sex on Originality

When grouped by Sex, Levene's test for homogeneity of variance found significant results for Originality (p = .005), as well as the covarying Shipley score (p = .024) and Word Count (p = .024). This suggests that the male-female variances were unequal and that the ANCOVA results should be interpreted with caution, although ANCOVA is considered to be robust to such violations. The probability plots indicate that the data do not deviate significantly from expected normal values (Figures 1, 5 and 6).

Although the ANCOVA did not detect a significant difference between male and female participants for the Shipley scores, a one-way ANOVA did yield a significant result (F = 15.998, p = .0006), with male participants scoring higher than females (M = 50.92 vs. M = 42.67). Males also wrote significantly more words than females (M = 336.25 vs. M = 303.08). With these covariates accounted for, a significant Originality difference was found (Table 8). Although a comparison of the group means before and after adjustment show that the covariates were accentuating the difference in Originality, the male participants still used significantly more unique words in their stories (Table 9).

DISCUSSION

Considering the results that were obtained, the null hypothesis – that there is no difference in creative problem-solving ability between groups with sleep and waking activity during the task interval – was retained. The experimental hypothesis was not confirmed. There are several possible explanations for these results.

Firstly, general creative aptitude was not controlled for in the analysis. Although the Creative Achievement Questionnaire was administered to the participants, the scores were not used in the analyses, because they did not significantly covary with any of the dependent variable measures. The questionnaire does not directly test creative aptitude, but rather the respondents' prior creative achievements, with the assumption that this indicates their creative ability. This may not be an effective way to measure creativity with youthful samples like this study's, however, as they may not have had enough opportunities to accumulate creative achievements in any field. Consequently, the CAQ scores were uniformly low for both groups and it appeared that the questionnaire gave only a crude measure of baseline creativity. It is possible that differing levels of pre-existing creative ability masked the effect of the sleep versus waking incubation, leading to the non-significant results.

Secondly, the sample size was possibly too small to produce significant results for the dependent variables. There was no consistency in the differences between means, as the WAKE Group scored higher for Fluency and Flexibility than the SLEEP Group, but lower for Originality.

Thirdly, the operationalisation of creative performance into Fluency, Flexibility and Originality might not be the most effective. It is possible that these measures were not sensitive to ways in which elements of the stories interacted to produce a Gestalt-like effect, that may be more indicative of creativity than counting and categorizing words. Thus, the stories may need to be evaluated as in a different manner to produce a meaningful measure of their creativeness.

Fourthly, it is likely that the sleep clinic environment compromised the quality of the participants' sleep. Most of these participants reported disturbed sleep during the night, which was confirmed by the polysomnograph data. Furthermore, the SLEEP Group participants were discouraged from consuming fluids once they arrived at the clinic, as they would be unable to relieve themselves during the night while attached to the electrodes, unless they used a sluice bottle or bedpan. Consequently, none of the SLEEP Group participants drank for a period of at least 10 hours and some of them may have become mildly dehydrated. Research indicates that mild dehydration raises blood cortisol levels (Ritz & Berrut, 2005), impairing learning, concentration and normal sleep patterns, as previously discussed (Plihal

& Born, 1999). The resulting minor cognitive impairments may have cancelled out the beneficial effect of sleep for those participants.

Lastly, one must consider the possibility that sleep does not affect creative problem-solving. The results do not provide conclusive evidence to support the hypothesis. The gathered evidence previously discussed suggests that there should be a relationship between sleep and creativity. There is a reasonable chance that this relationship may be uncovered with improvements to the experimental design.

The correlation matrix revealed some interesting results that were not directly related to the hypothesis. The significant correlation between Fluency and Flexibility (r = .51) can be interpreted as an increase in semantic associations between list-words (Flexibility) as more list-words are used in the story (Fluency). This correlation was only moderate, however, suggesting that a large portion of the semantic associations were between list- and non-list words. These associations were not accounted for in the analysis, as the semantic relatedness of the non-list words could not be established to a reasonable standard of reliability and validity.

The correlation between Originality and SILS scores suggest that performance on both measures was at least partly based on the participants' vocabulary. The first part of the Shipley scale evaluates vocabulary and the participants' knowledge of words would play a role on the number of unusual words they could use in the story, measured as Originality. Part 1 of the SILS and Originality were significantly correlated (r = .52).

The relationship between Flexibility and Recall is less easily explained, however. After the participants recalled the words, they received the same word list for the story-writing task. Therefore, they did not have to rely on their long-term memory to know which words to include in the stories. If Recall indicates how successfully the participants encoded the words from Session 1, it may indirectly reflect how well they incubated the words during the Interval period, regardless of their state of consciousness during that time. Participants who incubated the words more effectively would presumably be more successful at developing an interesting narrative that connects the words in an unconventional manner. If this phenomenon was the case, it illustrates the importance of long-term memory consolidation for incubation and insight (Christensen & Schunn, 2005; Wagner et al, 2005).

Although prior literature suggests that there are no overall significant differences in creativity between males and females, secondary analyses in this study found that males , across both conditions, scored higher for Word Count, Originality and SILS scores. One relevant sex difference in creativity that may explain these results is that males tend to produce more results on divergent tasks, compared to females, when specifically instructed to "be creative" (Katz & Poag, 1978). Word Count and Originality are both measures of ideational fluency to some extent, as they represent straightforward quantities of output, and are therefore similar to most other divergent task measures. It is not clear, however, why the male participants would score higher on the Shipley scale, unless random error due to small sample size played a role.

There are several ways in which the experimental procedure could be improved in future research. (A) A better direct measure of general creative aptitude needs to be found to control for variations in this potentially confounding variable. (B) A larger sample size will promote a higher probability of significant differences being found. A power analysis indicates that a sample $n = 36$ is required for a significant result with a moderate effect size ($f = .25$) and a power value of .696. (C) Sleeping conditions need to be improved for the sleep clinic participants. Participants may need to sleep without electrodes and other restrictions to improve their comfort levels and quality of sleep. Polysomnographic data is useful however, especially for future research. An alternative strategy might be to give the participants a "practice" night to accustom themselves to the sleep clinic environment, before gathering data. This is a common approach in sleep research, but was not feasible in this study for logistical reasons.

One proposed expansion to this study is to include another sleep group, with disruptive awakenings during periods of REM sleep. This will help to isolate the potential role that REM sleep plays in creative incubation and insight. Although many people believe that dreams are sources of creative inspiration and "to sleep on it" is an effective method of problem-solving, there is still little empirical evidence to support these notions. More research is required to understand the effect of sleep on creative problem-solving.

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Footnotes

1. For this measure, the word-pairs *teacher/school* and *sailor/captain* were also excluded. Many of the stories used teachers, sailors and captains as protagonists. A problem arose where the participants appeared to associate the word as protagonist with every other list-word used, through the logic of the narrative. At the same time, these associations were not always explicit, as the writers used pronouns and other linguistic devices in places to indicate the protagonist. These ambiguities made it difficult to categorise the *teacher, sailor* and *captain* pairs with any certainty.

Appendix A

CREATIVE ACHIEVEMENT QUESTIONNAIRE

Shelley Carson
Harvard University

I. *Place a check mark beside the areas in which you feel you have more talent, ability, or training than the average person.*

__visual arts (painting, sculpture)
__music
__dance
__individual sports (e.g. tennis, golf)
__team sports
__architectural design
__ entrepreneurial ventures
__creative writing
__humor
__inventions
__scientific inquiry
__theater and film
__culinary arts

II. *Place a check mark beside sentences that apply to you. Next to sentences with an asterisk (*), write the number of times this sentence applies to you.*

A. Visual Arts (painting, sculpture)

__ 0. I have no training or recognized talent in this area. (Skip to Music).
__ 1. I have taken lessons in this area.
__ 2. People have commented on my talent in this area.
__ 3. I have won a prize or prizes at a juried art show.
__ 4. I have had a showing of my work in a gallery.
__ 5. I have sold a piece of my work.
__ 6. My work has been critiqued in local publications.
* __ 7. My work has been critiqued in national publications.

B. Music

__ 0. I have no training or recognized talent in this area (Skip to Dance).
__ 1. I play one or more musical instruments proficiently.
__ 2. I have played with a recognized orchestra or band.
__ 3. I have composed an original piece of music.
__ 4. My musical talent has been critiqued in a local publication.
__ 5. My composition has been recorded.
__ 6. Recordings of my composition have been sold publicly.
* __ 7. My compositions have been critiqued in a national publication.

C. Dance

__ 0. I have no training or recognized talent in this area (Skip to Architecture)
__ 1. I have danced with a recognized dance company.
__ 2. I have choreographed an original dance number.
__ 3. My choreography has been performed publicly.
__ 4. My dance abilities have been critiqued in a local publication.
__ 5. I have choreographed dance professionally.
__ 6. My choreography has been recognized by a local publication.
* __ 7. My choreography has been recognized by a national publication.

D. Architectural Design

__ 0. I do not have training or recognized talent in this area (Skip to Writing).
__ 1. I have designed an original structure.
__ 2. A structure designed by me has been constructed.
__ 3. I have sold an original architectural design.
__ 4. A structure that I have designed and sold has been built professionally.
__ 5. My architectural design has won an award or awards.
__ 6. My architectural design has been recognized in a local publication.
* __ 7. My architectural design has been recognized in a national publication.

E. Creative Writing

__ 0. I do not have training or recognized talent in this area (Skip to Humor).
__ 1. I have written an original short work (poem or short story).
__ 2. My work has won an award or prize.
__ 3. I have written an original long work (epic, novel, or play).
__ 4. I have sold my work to a publisher.
__ 5. My work has been printed and sold publicly.
__ 6. My work has been reviewed in local publications.
* __ 7. My work has been reviewed in national publications.

F. Humor

__ 0. I do not have recognized talent in this area (Skip to Inventions).
__ 1. People have often commented on my original sense of humor.
__ 2. I have created jokes that are now regularly repeated by others.
__ 3. I have written jokes for other people.
__ 4. I have written a joke or cartoon that has been published.
__ 5. I have worked as a professional comedian.
__ 6. I have worked as a professional comedy writer.
__ 7. My humor has been recognized in a national publication.

G. Inventions

__ 0. I do not have recognized talent in this area.
__ 1. I regularly find novel uses for household objects.
__ 2. I have sketched out an invention and worked on its design flaws.
__ 3. I have created original software for a computer.
__ 4. I have built a prototype of one of my designed inventions.
__ 5. I have sold one of my inventions to people I know.
* __ 6. I have received a patent for one of my inventions.
* __ 7. I have sold one of my inventions to a manufacturing firm.

H. Scientific Discovery

__ 0. I do not have training or recognized ability in this field (Skip to Theater
__ 1. I often think about ways that scientific problems could be solved.
__ 2. I have won a prize at a science fair or other local competition.
__ 3. I have received a scholarship based on my work in science or medicine.
__ 4. I have been author or coauthor of a study published in a scientific journal.
* __ 5. I have won a national prize in the field of science or medicine.
* __ 6. I have received a grant to pursue my work in science or medicine.
__ 7. My work has been cited by other scientists in national publications.

I. Theater and Film

__ 0. I do not have training or recognized ability in this field.
__ 1. I have performed in theater or film.
__ 2. My acting abilities have been recognized in a local publication.
__ 3. I have directed or produced a theater or film production.
__ 4. I have won an award or prize for acting in theater or film.
__ 5. I have been paid to act in theater or film.
__ 6. I have been paid to direct a theater or film production.
* __ 7. My theatrical work has been recognized in a national publication.

J. Culinary Arts

__ 0. I do not have training or experience in this field.
__ 1. I often experiment with recipes.
__ 2. My recipes have been published in a local cookbook.
__ 3. My recipes have been used in restaurants or other public venues.
__ 4. I have been asked to prepare food for celebrities or dignitaries.
__ 5. My recipes have won a prize or award.
__ 6. I have received a degree in culinary arts.
* __ 7. My recipes have been published nationally.

K. Please list other creative achievements not mentioned above.

_____

_____

_____

III. *Place a check mark beside sentences that apply to you.*

__ One of the first things people mention about me when introducing me to others is my creative ability in the above areas.
__ People regularly accuse me of having an “artistic” temperament.
__ People regularly accuse me of being an “absent-minded professor” type.

SCORING OF THE CREATIVE ACHIEVEMENT QUESTIONNAIRE

Part I is an indicator of areas in which the participant feels he or she has talent or natural ability. Part II is an indicator of actual achievements. (Note that section K is included so that participants who have achievements in domains outside of the arts and sciences can be acknowledged. Answers in section K are not scored.) Part III includes questions that may be useful to the investigator's specific line of inquiry (you may add your own questions to this section of the questionnaire).

Score only checkmarks in Part II of the questionnaire.

- Each checkmarked item in Part II receives the number of points represented by the question number adjacent to the checkmark.
- Sum the total number of points within each domain to determine the domain score.
- Sum all ten domain scores to determine the total CAQ score.

In certain cases, you may be comparing scores of specialized participants within a domain (e.g. a sample of creative writers). In these cases, you may obtain an addition creative productivity score looking at the items marked by an asterisk, and multiplying the number of times the item has been achieved by the number of the question to determine points for that item.

Appendix B

SHIPLEY INSTITUTE OF LIVING SCALE

Name:_____ Sex: M F Age:_____
Education:_____ Occupation:_____Today's Date:_____

Instructions: In the test below, the first word in each line is printed in capital letters. Opposite it are four other words. Circle the one word which means the same thing, or most nearly the same thing, as the first word. If you don't know, guess. Be sure to circle the one word in each line that means the same thing as the first word.

EXAMPLE:

LARGE	red	big	silent	wet

1. TALK	draw	eat	speak	sleep
2. PERMIT	allow	sew	cut	drive
3. PARDON	forgive	pound	divide	tell
4. COUCH	pin	eraser	sofa	glass
5. REMEMBER	swim	recall	number	defy
6. TUMBLE	drink	dress	fall	think
7. HIDEOUS	silvery	tilted	young	dreadful
8. CORDIAL	swift	muddy	leafy	hearty
9. EVIDENT	green	obvious	sceptical	afraid
10. IMPOSTER	conductor	officer	book	pretender
11. MERIT	deserve	distrust	fight	separate
12. FASCINATE	welcome	fix	stir	enchant
13. INDICATE	defy	excite	signify	bicker
14. IGNORANT	red	sharp	uninformed	precise
15. FORTIFY	submerge	strengthen	vent	deaden
16. RENOWN	length	head	fame	loyalty
17. NARRATE	yield	buy	associate	tell
18. MASSIVE	bright	large	speedy	low
19. HILARITY	laughter	speed	grace	malice
20. SMIRCHED	stolen	pointed	remade	soiled
21. SQUANDER	tease	belittle	cut	waste
22. CAPTION	drum	ballast	heading	ape
23. FACILIATE	help	turn	strip	bewilder
24. JOCOSE	humorous	paltry	fervid	plain
25. APPRISE	reduce	strew	inform	delight
26. RUE	eat	lament	dominate	cure
27. DENIZEN	senator	inhabitant	fish	atom
28. DIVEST	dispossess	intrude	rally	pledge
29. AMULET	charm	orphan	dingo	pond
30. INEXORABLE	untidy	involatile	rigid	sparse
31. SERRATED	dried	notched	armed	blunt
32. LISSOM	moldy	loose	supple	convex
33. MOLLIFY	mitigate	direct	pertain	abuse
34. PLAGIARIZE	appropriate	intend	revoke	maintain
35. ORIFICE	brush	hole	building	lute
36. QUERULOUS	maniacal	curious	devout	complaining
37. PARIAH	outcast	priest	lentil	locker
38. ABET	waken	ensue	incite	placate
39. TEMERITY	rashness	timidity	desire	kindness
40. PRISTINE	vain	sound	first	level

PART II

Instructions: Complete the following by filling in either a number or a letter for each dash (_____). Do the items in order, but don't spend too much time on any one item.

EXAMPLE: A B C D __

1. 1 2 3 4 5 __
2. white black short long down __ __
3. AB BC CD D__
4. Z Y X W V U __
5. 12321 23432 34543 456__ __
6. NE/SW SE/NW E/W N/__
7. escape scape cape __ __ __
8. oh ho rat tar mood __ __ __ __
9. A Z B Y C X D __
10. tot tot bard drab 537 __ __ __
11. mist is wasp as pint in tone __ __
12. 57326 73265 32657 26573 __ __ __ __ __
13. knit in spud up both to stay __ __
14. Scotland landscape scapegoat __ __ __ __ee
15. surgeon 1234567 snore 17635 rogue __ __ __ __ __
16. tam tan rib rid rat raw hip __ __ __
17. tar pitch throw saloon bar rod fee tip end plank __ __ __ __ __ meals
18. 3124 82 73 154 46 13__
19. lag leg pen pin big bog rob __ __ __
20. two w four r one o three __

Summary Scores
V: Raw _____ T _____ **A:** Raw _____ T _____ **Total:** Raw _____ T _____
CQ: _____ **AQ:** _____

Appendix C

Word List

River	Bird
Letter	Stocking
Flower	Captain
Water	Nest
Stars	House
Machine	Garden
Shoe	School
Curtain	Moon
Street	Screw
Sailor	Window
Helmet	Head
Teacher	Envelope

Appendix D

Worked example of a story analysis

Participant 011 (WAKE Group)

Captain Haddock was a **school teacher** many years ago, but after time he lost interest and decided to buy a boat like the one his father had when he was younger. Although he calls himself a **sailor**, he has never in fact been aboard a ship at sea. Instead he sails the Amazon **river**, a dream he had since he was a child. Having begun his journey at the top of the **river** where it begins he is attempting to reach the end of it in the next 10 months. Before setting out on his journey he equipped the ship to the point where it resembled a normal **house**, although much smaller, that you might see in your **street**. It has a large **window** which overlooks a small patch of **garden** that manages to keep in perfect condition. Using the **river water** the **flower** patch is always bright and colourful and there even is a **bird** which made its **nest** atop one of the sails, that has made the **garden** its home. Although **Captain** Haddock travels alone he sends a **letter** to his wife at home during every stop he makes. To make sure the **letter** stands out when she gets mail he sends the **letters** in a bright orange **envelope**. The **captain** takes time to write these **letter**s every night while he sits on his open deck admiring the many **stars** and often bright **moon** which provide enough light not to need a lamp. To protect himself from the many biting insects, **Captain** Haddock wears a thick pair of **stockings** he bought at a village in the jungle. Whenever he needs any supplies, he stops at whatever village he happens to see buried in the thick jungle foliage. The items he recently found astonished him as he never thought he would find such things in such a rural area. He even found a **machine** that is able to **screw** bolts in his sails, as well as a traditional tribal hat that is made of wood and could be used as a **helmet**. However, one thing could never find was a pair of **shoes**, something he desperately needed as during a storm one night his deck became flooded and washed on shoe into the **river**.

Fluency

Total list-word frequency: 33

List-words used: 22

Fluency = 1.5

Flexibility:

Window-garden, water-flower, river-flower, bird-garden, nest-garden, letter-stars, letter-moon, shoe-river

Flexibility = 8

Originality:

Lamp, mail, jungle, supplies, foliage, item, area, hat, wood, bolt, storm,

Originality = 11

Table 1. Fluency ANCOVA Summary

	SS	df	MS	F	p
Word Count	0.561	1	0.561	10.04	0.005
Group	0.191	1	0.191	3.42	0.079
Error	1.117	20	0.056		

Table 2. Fluency Descriptive Statistics

	N	Mean	Adjusted Mean	St. dev.
WAKE	12	1.41	1.41	0.37
SLEEP	12	1.21	1.22	0.13
Total	24	1.32		0.29

Table 4. Flexibility ANCOVA Summary Table

	SS	df	MS	F	p
Recall	111.306	1	111.306	5.164	0.034
Group	17.22	1	17.20	0.799	0.382
Error	452.694	21	21.557		

Table 5. Descriptive Statistics for Flexibility

	N	Mean	Adjusted Mean	St. Dev.
WAKE	12	8.50	8.14	5.27
SLEEP	11	9.50	9.86	4.85
Total	23	9.00		4.98

Table 6. Originality (effect of Level of Consciousness) ANCOVA Summary

	SS	df	MS	F	p
Shipley	178.2	1	178.2	5.582	0.028
Word Count	105.0	1	105.0	3.291	0.085
Group	16.1	1	16.1	0.504	0.486
Error	638.3	20	31.9		

Table 7. Originality (effect of Level of Consciousness) Descriptive Statistics

	N	Mean	Adjusted Mean	St. Dev.
WAKE	12	7.58	7.09	6.14
SLEEP	12	8.25	8.74	7.58
Total	24	7.92		6.76

Table 8. Originality (effect of Sex) ANCOVA Summary

	SS	df	MS	F	p
Shipley	6.5	1	6.5	0.251	0.622
Word Count	122.6	1	122.6	4.719	0.042
Sex	134.7	1	134.7	5.186	0.034
Error	519.6	20	26.0		

Table 9. Originality (effect of Sex) Descriptive Statistics

	N	Mean	Adjusted Mean	St. Dev.
Female	12	4.00	4.79	2.763
Male	12	11.83	11.05	7.371
Total	24	7.92		6.756

Figure 1. Probability Plot for Word Count

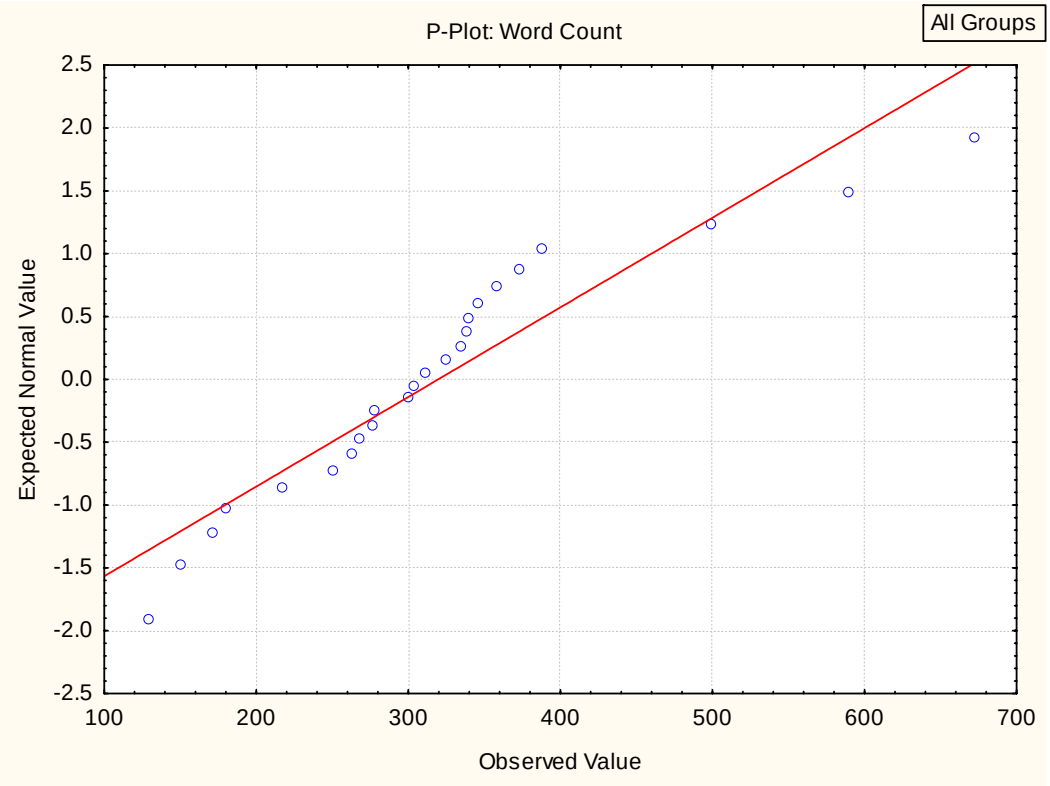

Figure 2. Probability Plot for Fluency

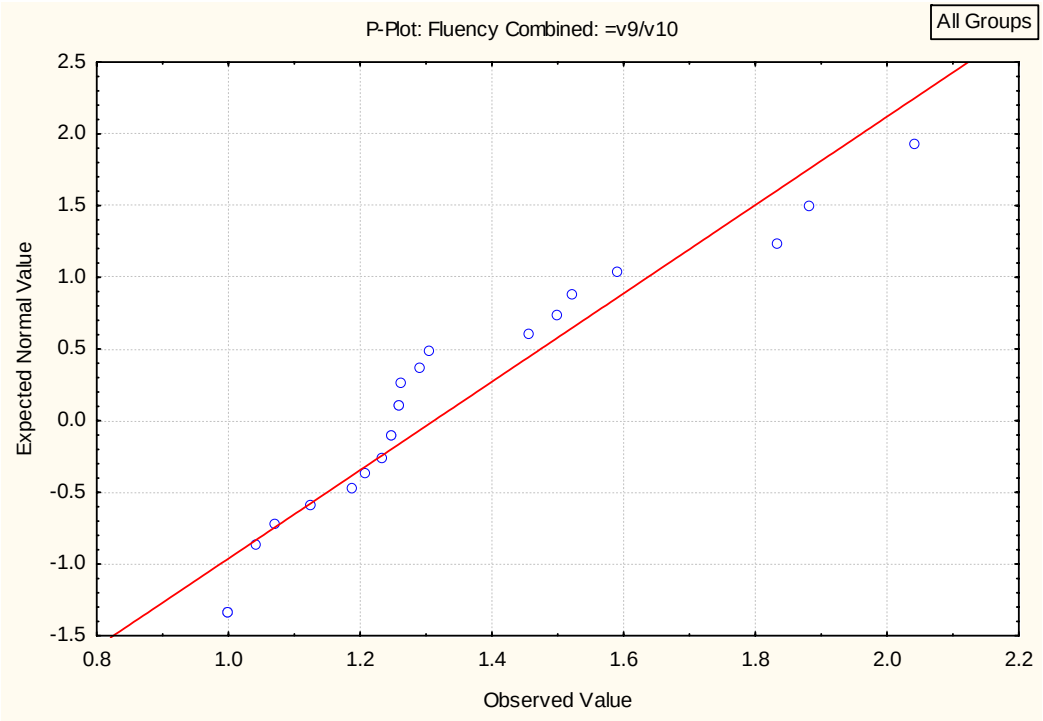

Figure 3. Probability Plot for Flexibility

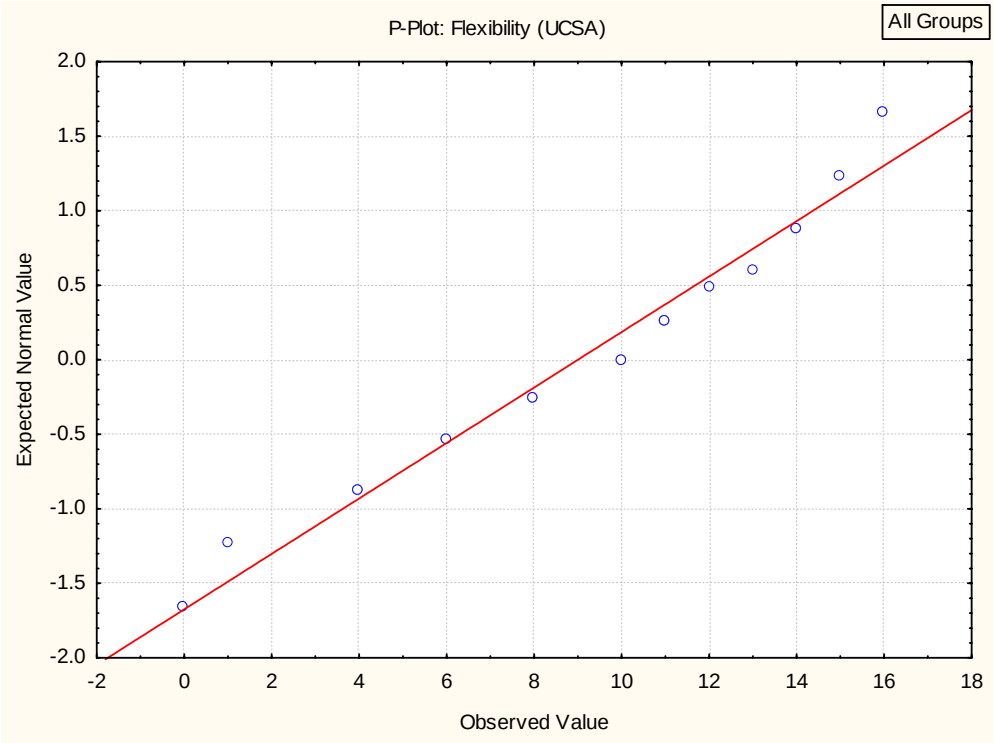

Figure 4. Probability Plot for Recall

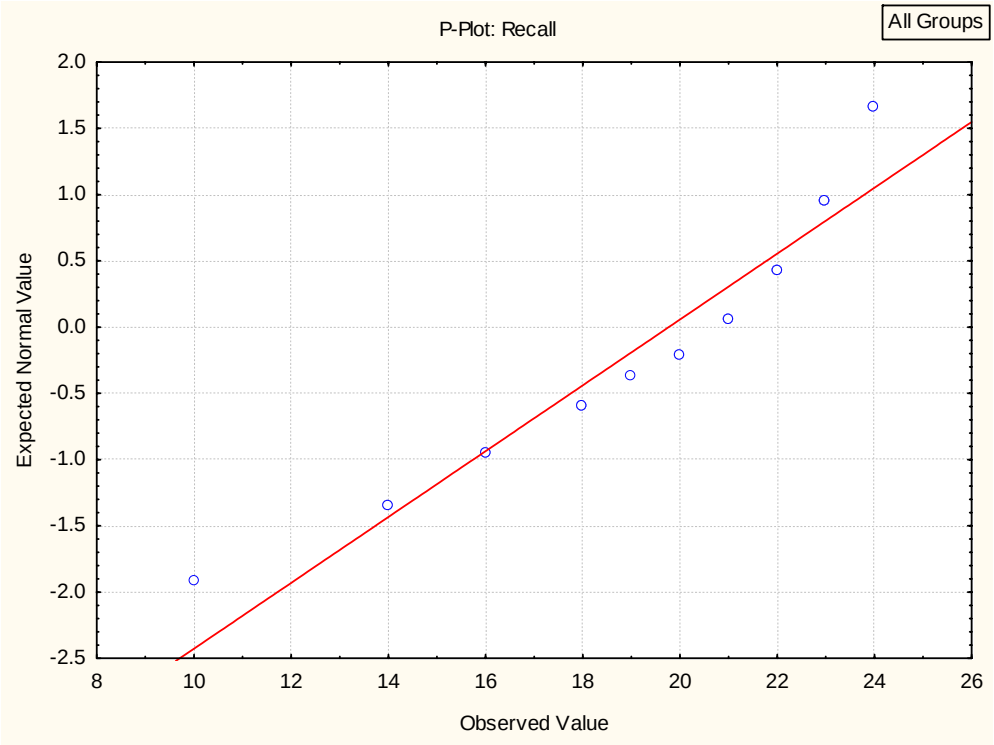

Fig. 5 Probability Plots for Shipley Scores

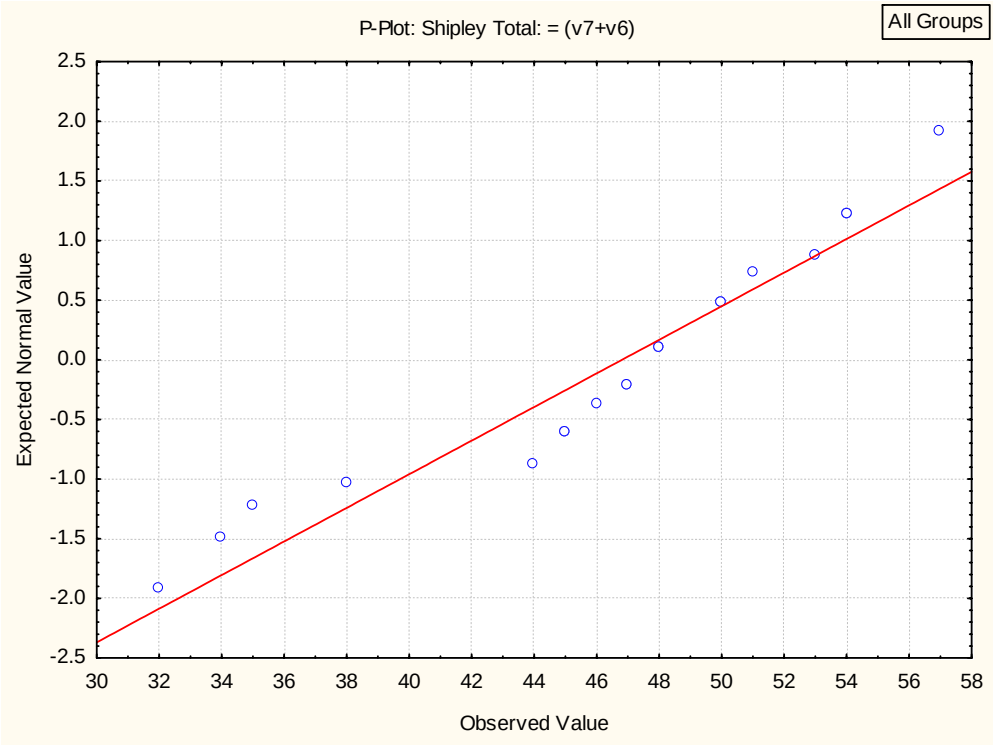

Figure 6. Probability Plot for Originality