# The Role of Sleep in Creative Task Performance

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**COMPULSORY DECLARATION**

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

Signature:________________________________________Date:____________________

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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. This study investigated the effects of sleep on performance with verbal and visual tasks that explicitly require 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 REM-deprived sleep, daytime wakefulness, or no interval between preparation and execution, but there would be no difference in performance between the participants in terms of convergent cognition. The study was a 4-level, single-factor design, with state of consciousness as the manipulated variable. Participants ($n$ = 87) were recruited from the university undergraduate population. Participants memorised a wordlist for task preparation and then, after an interval of either normal sleep, REM-deprived sleep, waking activity, or no interval, used the same wordlist to write a creative short story for task execution. The stories were assessed for creativity-related constructs by the researcher and independent raters. Participants also completed a visual design fluency task at both stages of the study, following a 4-level, single-factor, repeated-measures design. Participants' scores on the Torrance Test of Creative Thinking (TTCT) Verbal Edition and the Shipley Institute of Living Scale (SILS) were used to control for general creative ability and IQ respectively. ANCOVA, repeated measures ANOVA, and Fisher's $r$ to $z$ transformation statistics were used to analyse the data. Although generally the hypotheses were not directly supported by the data obtained, trends suggest that there was a connection between sleep and creativity, especially an apparent interaction between baseline creativity and the type of interval. Based on the indirect evidence obtained, directions for future research for investigating sleep and creativity are discussed.

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# INTRODUCTION

There are many extraordinary stories about people who gained creative inspiration from their dreams. Mary Shelley's novel *Frankenstein* was apparently inspired by a dream, as was Robert Louis Stevenson's novel *Treasure Island* (Todman, 2008). After years of work, Dmitry Mendeleyev developed the structure of the periodic table of elements from dream-inspired thoughts (Stickgold & Walker, 2003). Otto Loewi's experiment to demonstrate the chemical basis of synaptic transmission was based on a dream (Todman, 2008). Such anecdotes are easy to find, but 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., Pagel & Kwiatkowski, 2003; Schredl & Erlacher, 2007) and have found that participants reported a significant effect of dreams on, for example, creative work and general problem solving. Of course, there are problems with this methodological approach. Participants may attribute too much influence to dreams because of personal bias, or may incorrectly recall the dream and the subsequent events. Confirmatory bias may also encourage people to remember the relatively few instances where dream content and waking life were coincidently similar, but ignore the majority of dreams that bear no resemblance to their waking life. Furthermore, such self-report research tends to be retrospective, rather than studying the problem-solving or creative process as it occurs under controlled conditions. Importantly, it is not clear whether the benefit to creativity might stem from recalled dreams specifically, or from other processes that occur during sleep that are not necessarily experienced as dreams.



Creativity itself is a notoriously difficult construct to study scientifically, not least because it is difficult to define precisely. This study will use, 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). The difficulties in measuring such processes may be one of the reasons why the sleep-creativity association has been a relatively neglected area of research in psychology. Recent studies, however, have demonstrated that there are effective methods of scientifically investigating the association between sleep and creativity.

Studies in this field can be classified as either “Big-C” research, which are studies of creative genius and eminent people, or “little-c” research, which are studies of creativity in the general population (Kaufman & Sternberg, 2007). Although Big-C research examines creative ability in a clearer and relatively purer form than little-c research, it has some flaws. For instance, Big-C research often uses retrospective historical analyses of famous individuals, or studies the behaviour of high-performing creative individuals; neither group is representative of the general population. Little-c research, although it may not demonstrate as clear effects as big-C research, has the advantage of producing results that are generalizable to the broader population; it therefore has the potential to offer more useful insights into creativity. The aim of this study was to investigate, using an empirical approach, the role that sleep and dreaming can play in creative task performance in the general population.



**Prior Cognitive and Behavioural 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). Convergent cognition is an important aspect of creativity, because the quality, relevance, and appropriateness of a response are considered to be criteria of success in most creative tasks (Kaufman & Sternberg, 2007; Plucker, Runco, & Lim, 2006). Most research in creativity, however, has focused on factors that influence divergent thinking, perhaps because divergent cognition more closely resembles what people usually consider to be creativity.

Brophy (2000) found that most people were inclined to either divergent or convergent thinking, rather than an equal combination of the two processes. In an attempt to describe the relationship between personality traits and convergent or divergent thinking, he conducted research with university students given the task of developing new ways to market their university and improve its operation. Brophy examined the students' performance on this task using content analysis of transcribed group discussions; he also collected the students' responses on various personality scales, such as the Myers-Briggs Personality Inventory (Myers & McCaully, 1985).

Brophy showed that divergent thinking was associated with personality traits such as a preference for autonomy, as well as complex symbol use and fantasy play. Furthermore, divergent thinkers showed a preference for ideation, which is generating ideas or potential solutions, over evaluation, which is judging those ideas according standards of logic. Students classified as divergent thinkers also preferred innovation to adaptation; for instance, they tended to prefer developing a completely new marketing strategy rather than modifying or altering an existing strategy. In addition, these students also tended to use intuition over reasoning, such as when developing multiple solutions inductively and in parallel, rather than developing a single solution in a linear, deductive style. Finally, the divergent thinkers displayed a greater tolerance for ambiguous stimuli, had higher levels of extroversion and were more likely to project an internal locus of control (i.e., they showed higher levels of self-confidence). In contrast, in this study convergent thinking was best predicted by a preference for reasoning, evaluation, adaptation, as well as tendencies toward ambiguity intolerance, introversion and an external locus of control. In summary, the research demonstrated that (a) divergent and convergent thinking are empirically distinct cognitive processes, and (b) personality factors influence preference for one or the other cognitive style.

Following Brophy's research, Meneely and Portillo (2005) investigated the relationships between personality, cognitive style, and performance on a design task. Participants were interior design students who were asked to design an item of furniture to be used for storing books and to create a 3-dimensional model of their ideas. The teaching staff at the college assessed these models. Participants also completed scales to assess personality traits, hemisphere dominance, and cognitive style; the latter measured on two dimensions of analytical-affective and global-local. Creative personality traits (e.g., independence, curiosity, ambition) did predict performance on the design task, but hemisphere dominance and preference for a particular cognitive style did not predict performance on the task. A number of the high-performing students showed left-hemisphere dominance and a preference for analytical over affective thinking, however. Furthermore, the researchers found that flexibility of cognitive style (e.g., students who alternated between analytical and affective thinking, rather than preferring one or the other) was associated with creative personality traits. The data supports the notion that preference for divergent or convergent thinking is based on personality factors, but also reinforces the importance of divergent *and* convergent thinking for superior creative performance.

Creative performance is not only influenced by personal factors, but by external conditions as well. For example, priming for abstract thought has been found to enhance divergent processing. 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 they do near-future events. The researchers asked their participants to imagine a scenario by asking themselves "What would your life be like", either for the next day, or in a years' time. Immediately afterwards, participants completed a problem-solving task using an unrelated scenario set in the present time. Results showed that when participants' cognitive processing was primed for abstract, imaginative thought (i.e., when they were required to imagine a scenario occurring in the next year), they performed better on a task requiring divergent thinking (e.g., generating solutions for an interior decorator) than they did on a task requiring convergent thinking (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 priming effect occurs across different creative modalities.

In summary, creative thinking comprises two distinct processes: divergent and convergent cognition. Divergent cognition involves generating ideas, and convergent cognition involves selecting the most appropriate ideas for implementation. A bias for either cognitive process in general and creative thinking depends not only stable factors such as personality, but on transient factors, such as environmental stimuli, as well. Importantly for this research, cues to think speculatively or imaginatively promote superior divergent cognition.

**Prior Neuropsychological Research into Creativity**

Danko, Starchenko, and Bechtereva (2003) investigated EEG cortical activity of subjects who were engaged in a variation of the remote associations task, where participants had to find nouns to link semantically unrelated words in sequence. 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. They also found diminished spatial synchronisation in the frontal and prefrontal regions of the brain, particularly in the midline area and left hemisphere, indicating lowered activity.

Fink and Neubauer (2006) also tested performance on verbal creativity tasks while measuring electroencephalograph (EEG) alpha waves in participants. The first task required the participants to give insights into unusual situations (e.g., “A light in the darkness”), by suggesting possible causes and consequences. In the second task, participants were presented with fantastical scenarios (e.g., “Imagine, there were a creeping plant rising up to the sky. What would await you at the end of this plant?”) and again were asked to suggest possible causes and consequences of the situations. For both tasks, participants were instructed to generate as many ideas as possible and to strive to be as original as possible; thus, their capacity for divergent thinking was assessed.

Fink and Neubauer found that divergent thinking in the tasks was associated with lower cortical arousal, diffuse 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. Decreased cerebral blood flow in the posterior parietal regions, with increased blood flow in the occipital regions, is also found in alternate states of consciousness such as hypnosis (Rainville et al., 1999); these variations in cortical activity and blood flow suggest that increased ideation and generation of internal imagery corresponds to decreased attendance towards external stimuli.

Consistent with this line of thought, Fink and Neubauer (2006) 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. Symbolic, or metaphoric, thinking, which has been long associated with dreaming, has been associated with divergent cognition (Glicksohn, Kraemer, & Yisraeli, 1993). Furthermore, instructions to subjects to defocus their attention away from a word-generation task leads to better performance when resuming the task, by promoting a period where the subjects' fixation on the strongest associations is reduced (Howard-Jones & Murray, 2003). In this primary 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.

The results from the studies reviewed in this section raise the possibility that activity in frontal brain regions needs to be inhibited for divergent thinking to occur. This is consistent with divergent/convergent creativity theory. Divergent thinking involves generating ideas, whereas convergent thinking involves judging those ideas, selecting the most appropriate responses and inhibiting the least appropriate responses; these cognitive functions are associated with frontal cortical activity. Although these studies show that the frontal cortical regions are important for convergent thinking and need to be inhibited for divergent thinking to occur, there is not enough research investigating which regions become *more* active during divergent thinking. Another limitation here is that EEG studies (a) can only show cortical activity close to the surface of the brain, and (b) have low spatial resolution (Zillmer, Spiers, & Culbertson, 2008). Therefore, other kinds of neuroimaging techniques (e.g., functional magnetic resonance imaging) are required to investigate the role of deeper sub-cortical structures, and thus providing more detailed information about general neural activity during creative thinking.

In an attempt to address some of these shortcomings in previous neuroimaging research, Moore et al. (2009) investigated the relationship between divergent thinking capability and brain structure in a structural MRI paradigm. They administered the Torrance Test of Creative Thinking (TTCT; Torrance, 2008) as a measure of creative aptitude, and had each participant undergo a volumetric MRI. They hypothesised a positive correlation between visuospatial divergent thinking and volume of right hemisphere white matter and corpus callosum. This prediction was based on the idea that increased connectivity between brain regions (as illustrated by the pattern of diffuse cortical activity found in previous research) facilitates divergent thinking. Their predictions were not supported, however. The data suggested a negative correlation between TTCT scores and corpus callosal volume, and no relationship between divergent thinking aptitude and white matter volume in either hemisphere. The researchers interpreted their findings as suggesting that neural pruning is important for the development of creative aptitude, and that the relative independence between brain hemispheres facilitates divergent thinking. Although the research described above shed some light on the neural basis of creativity, a functional MRI study would still be required to investigate creative thinking as it occurs, and, more specifically, to investigate neural activity at different stages of the creative process.



Several empirical studies from outside the field of neuropsychology provide data to support the theoretical importance of changes in consciousness for creativity. For instance, dream reports from highly creative individuals tend to show more evidence of primary cognition, such as symbolism, condensation, and unusual combinations, than dream reports of people with only average creativity (Domino, 1976). In this context, "condensation" refers to instances where objects or people are fused in the dream; "unusual combinations" are instances where characters or objects occur together in a dream in a scenario that would be unlikely in reality.[1] Another study found that participants who received hypnotic suggestions to dream creative solutions for their personal problems reported better outcomes than other participants who received rational-cognitive counselling (Davé, 1979). Davé recruited participants who were experiencing some kind of problem in their personal or professional lives and randomly allocated them to one of three treatment types: hypnotic induction,

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[1] Domino recruited high-school students for the study dividing the participants according to whether or not they scored above or below the 50th percentile for a creativity test and whether or not they were nominated by their teachers for their creative achievements in the classroom.

rational-cognitive, or personal interviews. Participants in the hypnosis group received suggestions to generate spontaneous mental imagery first, then later suggestions to dream solutions to their problems. All participants were contacted a week later and asked about the status of their problem. A successful outcome was counted when participants reported a positive change in status for the problem, could describe the solution they implemented, and reported satisfaction with the outcome.

More recently, studies on systematic-relaxation techniques show that a relaxed state of mind has a short-term benefit for divergent thinking in verbal tasks (Krampen, 1997). The effect of relaxation appears to be most pronounced in younger people. Krampen found that school children showed greater improvement on tasks of associational and ideational fluency following a session of systematic relaxation, compared with their peers who spent the same period resting with normal consciousness. Krampen repeated the study with college undergraduates and found greater improvements in general verbal fluency in the relaxed group. The same effect was found when using autogenic training instead of systematic relaxation, suggesting that the particular technique was not important. In contrast, when studying an elderly sample under the same conditions, Krampen found greater improvements in short-term memory and concentration, but not on creativity measures, for the relaxed group. In sum, these data suggest that states of reduced consciousness or alertness can have a positive effect on creative problem-solving and task performance.



## Sleep, Dreaming, Memory and Creativity

Sleep periods are divided into distinct stages, based on changes in neural and physiological activity; the overall structure is termed sleep architecture (Green, 1994). Neural activity during sleep is most commonly measured using EEG technology. While waking consciousness is characterised by fast, desynchronised neural activity with no discernable wave pattern, sleeping consciousness is characterised by EEG synchronisation with distinctive wave patterns that increase in amplitude and decrease in frequency as subjects enter deeper stages of sleep. *Stage 1 sleep* has predominantly alpha waves of 4-8 Hz, with some theta waves (Zillmer, Spiers, & Culbertson, 2008), while heart rate, muscle tension, and body temperature gradually decrease. *Stage 2 sleep* has larger, slower theta waves predominating, although 1-second bursts of fast activity in the 12-16 Hz range, known as *sleep spindles*, also occur in this stage. *Stage 3 sleep* has a combination of theta and larger, slower delta waves in the 1-3 Hz range, with some sleep spindles. *Stage 4 sleep* is the deepest stage, as subjects do not wake easily, and has only delta waves of approximately 1 Hz in frequency. Stage 4 sleep usually lasts for about 30 minutes before subjects pass through sleep stages 3, 2, and 1, in that order, before entering *rapid eye movement* (*REM*) sleep for the first time. Healthy subjects normally repeat the cycle of ascending and descending sleep stages, without re-entering stage 4 sleep, several times in a night.

Of all periods of sleep, neural activity in the REM stage most closely resembles that of waking consciousness. REM-stage sleep also contradicts the general pattern of increasingly larger and slower waveforms as subjects pass through the other sleep stages, because it is characterised by fast, desynchronised, and mixed waveforms, similar to waking activity. Furthermore, as the name suggests, REM is characterised by random, sudden eye movements, unlike the other sleep stages where eye movement is either slow and rhythmic, or minimal. Reduced power in alpha waves (8-12 Hz) in the occipital regions is commonly found in response to waking task performance with external stimuli and intense visual imagery; a similar pattern of neural activity is found during Stage 2 and REM sleep (Esposito, Nielsen, & Paquette, 2004).

There are neurochemical differences between REM and wakefulness, however. For instance, during REM sleep there are reduced levels of acetylcholine and norepinephrine in the neocortex, with increased acetylcholine levels in the hippocampus suppressing feedback to the neocortex; this is the inverse pattern to that occurring during waking consciousness. Cai et al (2009) suggest that this arrangement of neurotransmitter levels in REM sleep may facilitate spreading activation of association networks, which therefore aids divergent cognition.

Reported dream experiences during REM sleep also show a qualitative change over the course of the night, with increasing complexity and organisation into narrative structures (Cipolli, Bolzani, & Tuozzi, 1998). Cipolli et al. (1998) also found that verbal content increases in dreams over the course of the night, suggesting that cognitive resources become more available, especially in the late stages of sleep where REM periods are longer.

With regard to the overall sleep process, many studies show the importance of sleep for long-term memory. This association could be especially relevant for creative problem-solving, as subjects draw on both *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. Developing new associations between declarative memories to form new knowledge structures has been identified as an important basis for creative thinking (Scott, Lonergran, & Mumford, 2005)[2].

In a seminal 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 hippocampus and related structures in the limbic system have numerous glucocorticoid receptors (Alderson & Novack, 2002), suggesting that elevated levels of cortisol secretion could affect memory consolidation. Plihal and Born tested their participants at a sleep laboratory over a period from between 22:15 and 23:00 until approximately 3 hours after sleep onset. The participants completed a verbal paired associates learning task (an assessment of verbal declarative memory) and learnt a mirror tracing task (an assessment of non-declarative, or procedural, memory). Afterwards, they were allowed to sleep and received an intravenous dose of either cortisol or placebo until 2.5 hours after sleep onset. Participants were allowed up to 3 hours of slow wave sleep before



[2] Memory is not a unitary process; three distinct phases are typically identified in the construction of long-term memories. *Encoding* is the stage where new experiences or bits of information are transferred from short-term memory to long-term memory stores. *Consolidation* is the ongoing process whereby encoded memories are reorganised for more effective storage. *Retrieval* is the process when a particular encoded and consolidated memory is replayed and re-experienced (Zillmer, Spiers, & Culbertson, 2008).

they were awoken to retest their ability on the two memory tasks. The researchers found that subjects receiving a cortisol infusion performed worse than controls on the paired-associate learning task. No statistically significant between-group differences were found on the mirror-drawing task, however, suggesting that the cortisol effect does not impact significantly on procedural memory consolidation. Furthermore, the fact that pituitary-adrenal system, associated with cortisol secretion and stress responses was inhibited during early sleep may suggest that this sleep stage plays an important role in the consolidation of verbal declarative memory.

Subsequent studies have provided more data to confirm that the hippocampus plays a crucial role in declarative memory consolidation during sleep. Káli and Dayan (2004) theorized that during sleep, the hippocampus replays activation of recent memories for encoding episodic memory in the neocortex. They developed a simulated neural network to test their theoretical model of this hippocampal-cortical interaction. Specifically, they tested hippocampal replay, storage, access, and decoding of declarative memory. Similarly, Cipolli, Bolzani, Tuozzi, and Fagioli (2001) suggest that dream rehearsal (i.e., replay of daytime memories during the dreaming experience) consolidates declarative memory during sleep. Furthermore, a review of positron emission tomography (PET) imaging studies showed that an increase in hippocampal activity is associated with REM sleep, when most vivid dreaming normally occurs (Hobson, Pace-Schott, Stickgold, & Kahn, 1998).



Apart from theoretical models, empirical research has also between conducted to investigate the relationship between memory consolidation and sleep, but while some research has demonstrated an important role for REM sleep in episodic memory consolidation, there is also much debate around this relationship. Various studies have shown that REM is associated with episodic memory consolidation, procedural memory consolidation, specific types of episodic memory consolidation, or even that there is no relationship between REM and any type of memory consolidation. At least one study (Grieser, Greenberg, & Harrison, 1972) has shown that REM sleep is associated with consolidation of affect-laden, especially threatening, memories, whereas non-REM sleep is linked with consolidation of emotionally neutral memories. Grieser and colleagues selected participants who scored high on tests of ego strength. The participants were given a series of anagrams to solve; these were presented to them as an intelligence test. The anagram task was timed and many of the items were selected to be too difficult to solve within the time limit the participants were allocated. The participants were then given an interval of waking consciousness, REM-deprived sleep, or sleep with non-REM awakenings. After the interval, they were asked to recall (a) which items they had failed to solve (a question that would presumably act as a threat to ego) and (b) which items they had completed successfully (a question that would cue retrieval of non-threatening memories).

Participants in the REM-deprived group remembered significantly fewer failed items than the non-REM awoken group, but there was no difference for recall of non-threatening completed items. The researchers interpreted this finding in terms of repression: participants in the REM-deprived group were deprived of more opportunities to dream and were therefore unable access repressed material. Therefore, according to this interpretation, consolidation during sleep can also be a functional form of forgetting. Another interpretation may be that the participants thought more about the failed items after the anagram task because they still wanted to solve those items. In this case, REM sleep may play some role in solving the unresolved items. Participants in the REM-deprived group were unable to engage in this process, and therefore were more likely to forget the unsolved problems before the recall task. In other words, their lack of recall might not necessarily be related to the ego-threatening nature of those memories. The role that REM sleep might play in addressing pre-sleep cognitive concerns will be discussed later.



More recent studies have demonstrated a role for REM sleep in episodic memory consolidation. Protein synthesis in cortical cells occurs more frequently during REM sleep, which affects the long-term potentiation[3] of the cells and therefore long-term memory encoding (Mazzoni et al., 1999). Research has found that sleep deprivation, particularly the specific disruption of REM sleep, reduces the excitability of hippocampal cells (Yoo, Hu, Gujar, Jolesz, & Walker, 2007). Yoo et al. administered a memory encoding task to participants while conducting an fMRI scan. During scanning, participants had to memorise a

[3] Long-term potentiation involves neurochemical alterations to neurons, specifically to glutamate neurotransmitter receptors, that increase the likelihood of cells firing in the future, which has been linked to the formation of neural association networks and the encoding of long-term memories (Zillmer, Spiers, & Culbertson, 2008).

series of picture slides; they had to return 2 days later for a recognition task based on the encoded slides. Half of the participants were deprived of sleep for 35 hours prior to the scanning and encoding phase, while the others acted as a control, with normal sleep patterns. The researchers found that, in comparison to the controls, participants in the sleep-deprived group showed reduced activation in hippocampal and related temporal lobe regions during the encoding task, with correspondingly poorer performance on the subsequent recall task.

In a different study, elderly subjects who memorised words before sleep showed a positive correlation between post-sleep recall and relative length of non-REM (particularly Stage 2 sleep) and REM cycles combined (Mazzoni et al., 1999). In this study, the participants memorised a list of non-related word pairs before sleep onset. Upon awakening in the morning, they were asked to recall words from the list, using the other half of each pair as a cue. A previous testing session during the day, with the same memory task, was used to establish a baseline for the participants' capability. Better recall performance in the experimental session was significantly correlated with the length of combined REM/NREM periods, but there was no significant relationship with REM or NREM periods separately. These researchers found that the Stage 2 and REM cycles appeared to operate as a functional unit for memory consolidation, at least for verbal episodic memory, in other words, the memory consolidation process most likely occurred across both sleep stages.

The studies reviewed above all focused on declarative (primarily episodic) memory consolidation; comparatively few studies in the field have focused on non-declarative, or procedural, memory consolidation during sleep. Although the animal research they reviewed suggested a role for REM sleep in procedural memory consolidation, Rasch, Pommer, Diekelman, and Born (2008) found that REM-suppression using antidepressants resulted in actual *improvements* in learnt-skill performances in humans. Importantly, these researchers also found that administration of the antidepressants also had no effect on consolidation of verbal declarative memory. Suppressed REM participants had more Stage 1 and 2 sleep than controls, as well as more sleep spindles. The skill improvements in Rasch et al.'s participants were positively correlated with the frequency and density of sleep spindles, but not with any other characteristics of the sleep architecture.

The inconsistent findings for REM sleep in various studies such those described above suggest that Stage 2 sleep might be more important for memory consolidation than REM, or perhaps the interactions between sleep stages, concerning memory consolidation, may be more complex than currently understood. In addition, suppressing REM sleep chemically might have different effects than interrupting it with forced awakenings at REM stage-onset. Chemical suppression would mean that REM is replaced by another sleep stage, whereas forced awakenings mean that REM sleep is replaced by waking consciousness. Overall sleep length would not likely change with REM-suppression, whereas REM awakenings would effectively subtract the REM portion from the total period spent asleep. Importantly, when using REM-suppression, one would need to be cautious when attributing changes in post-sleep behaviour to a reduction in REM, because it is confounded by an increase in non-REM sleep. This confound is not present with REM awakenings.

Overall, then, the relationship between REM sleep and memory consolidation remains contentious. Research shows an interesting relationship between dreaming and memory consolidation, however. For example, Nielsen, Kuiken, Alain, Stenstrom, and Powell (2004) found that episodic memory in dream content usually originates from the preceding day, referred to as a "*day-residue effect"* (p. 327). A delayed inclusion or "*dream-lag effect"* (p. 327) is also present sometimes, with episodes dated approximately 7 days prior included in the dream content. Nielsen and colleagues drew these conclusions after asking participants to write a dream report for each night over a week. The researchers then rated each dream on criteria such as clarity of recall and intensity of emotions. After the week of dream reports, participants were asked to select one of their recorded dreams and compare it to events that occurred on a day randomly chosen by the researchers, ranging from 1 to 7 days prior to the dream. Participants had to select an event, from the target day, that most closely resembled the dream they selected and then write a detailed report of the event. They also had to rate their confidence in their memory for the event and the similarity of the event to the selected dream. Independent raters assessed the correspondence between the dream and event reports, and rated the texts for their relevance to a set of descriptors. Importantly, the data revealed that the delayed inclusion memories were usually associated with descriptors such as personal relationships, positive emotions and resolved problems, whereas the residual, previous-day memories were sometimes associated with descriptors related to pressing issues, problems and unresolved tasks.

Cipolli et al. (2001) found more evidence for the inclusion of recent episodic memories in dreams with a task where subjects had to memorise nonsense sentences shortly before entering sleep and then recall the sentences after waking the next morning. The nonsense sentences were matched for grammatical equivalence, were high in vivid, concrete content, and were long enough to make conscious rehearsal difficult (e.g., "In the bathroom the raven is painting a fish upon a radio and spinning a bust on the custard."). The participants were awoken close to the onset of three REM periods during three nights and were asked to report any dreams they may have had. The researchers used independent raters to judge associations between the dream contents and the nonsense sentences. 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, established by dream reports from prior control nights. The researchers also showed that cognitive concern with ideas or memories increased the likelihood of the relevant items appearing in dream content, perhaps by influencing the semantic and episodic memories accessed during sleep.



These studies (Cipolli et al., 2001; Nielsen et al., 2004) 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.

There is also evidence that the dreams of highly creative people are qualitatively different to those of people with normal creativity. For instance, one study showed that art students report more imaginative dreams, with more detail, than non-art students (Schechter, Schmeidler, & Staal, 1965). Schechter et al. asked art, science and engineering students to report their most recent dream, provide an interpretation for it, and describe any emotions or thoughts associated with the dream. Participants also completed a questionnaire on independence of judgement as a rating of their creative aptitude. Not only were the art students more likely to report dreams that rated high in imaginativeness, but imaginativeness was also strongly correlated to independence of judgement, confirming a relationship between dream content and creativity.

Similarly, other studies have shown that highly creative people report more unique and novel dream scenarios. For instance, Sylvia, Clark, and Monroe (1978) had two groups of participants (one that scored above the $80^{th}$ percentile on a battery of creativity tests and another that scored below the $20^{th}$ percentile on the same battery) spend two nights at a sleep laboratory and give dream reports during two REM awakenings each night and upon awakening each morning. The creative qualities of the dream reports were rated independent blind judges, who were able to assign the dream reports to the high- or low- creativity groups with accuracy above chance levels, based on the dream content alone. Highly creative participants reported more unusual dream settings, as well as more unique and novel elements, while the low creative participants reported dream settings similar to their normal environment, with more common, everyday elements.



Positive intercorrelations have been found for frequency of night- and daydreams, creativeness of those dreams, as well as frequency of need-achievement themes occurring in those dreams (Singer & Schonbar, 1961). In this study, participants were assigned to high- and low- creativity groups by scoring above or below the median on a daydreaming questionnaire. The questionnaire also required the participants to report an actual daydream, as well as write an unrelated short story. The interesting relationship between dreaming frequency and need-achievement themes in dream content supports previously mentioned research on the tendency for problems and concerns to appear in dream content.

One problem with dream-based research, however, is the intensely subjective nature of dreaming. Dream reports cannot be independently verified, so it is possible that highly creative people elaborate upon dreams as they are recalled. Another, related, problem is that more recent research has shown that REM dreams vary in quality during the night (Cipolli et al., 1998), which is a potential confound for dream content if participants are more likely to remember a late-sleep dream when reporting in the morning as opposed to during a REM awakening during the night. Furthermore, participants who report dreams in the morning, or at a later stage, would be more likely to produce an elaborated account, unlike REM-awakened participants, who tend to be too disorientated to give a "polished" dream report.

Although some evidence (e.g., the studies reviewed above) indicates that highly creative people sleep and dream differently to the norm, other research suggests that sleep may be negatively related to creativity, or at least is unimportant to creative people. Creative talent is associated with obsessiveness, single-mindedness and fluctuating periods of intense productivity (Healy & Runco, 2006). For instance, art students tend to prefer working in the hours after midnight, tend to perceive this time as more productive, and report more disrupted sleep-wake schedules, in comparison to management students (Wang & Chern, 2008). Highly creative children report more disturbed sleep than the norm (Healy & Runco, 2006). Thus, highly creative people may have difficulty falling asleep, they may not need as much sleep to perform optimally, or they may in fact have impaired productivity due to a sleep deficit. These possibilities require further investigation.



**Incubation and Insight**

Of course, the possible beneficial effects of sleep on creativity might not derive from the physiological state of sleep so much as the cognitive processes that can occur during sleep. Incubation and insight are important processes in creative problem-solving and appear to be active during sleep. *Incubation* is conventionally described as a passive process where individuals 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 usually defined as active 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 after a process of incubation. The authors asked their participants to solve puzzles, the solutions to 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 gained at a later stage from external stimuli that suggest new associations.

This is in contrast to what the authors termed *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. In this study, no opportunity was presented for significant unconscious processing, as might occur in sleep, for example.

It is important to note that, at times, incubation is not helpful for some forms of cognition. For example, some evaluative decision-making experiments (e.g., Acker, 2008; Lassiter, Lindberg, González-Vallejo, Bellezza, & Philips, 2009) used a protocol where participants were asked to memorise preselected positive and negative attributes about a set of objects, such as cars. Some participants were then allowed to take some time to think about which object was best; others engaged in a distracter task. Finally, both groups of participants offered a judgement about which object was best. These studies found that the participants in the conscious thinking group, who were presumably engaged in interactive incubation (as opposed to the participants in the distracter task group, who were presumably engaged in autonomous incubation), were more successful at selecting the better car and at ranking the cars in terms of their positive attributes.



Sleep, as a potential form of autonomous incubation, does not appear to aid general problem-solving (Cai, Mednick, Harrison, Kanady, & Mednick, 2009). According to Acker (2008), unconscious decision-making has been theoretically associated with divergent thinking. The tasks used in these decision-making experiments, however, are primarily evaluative in nature, rather than ideational. Theoretically, the underlying cognitive process in these tasks would more likely be associated with convergent thinking. Thus, it would seem that incubation facilitates divergent thinking, but not convergent thinking, as used in decision-making and in logical problem-solving.

In an example of how autonomous incubation in sleep can aid insight-based problem-solving, 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 that participants in the sleep group 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.

The beneficial effect of sleep on incubation may be based on specific phases of sleep. Although its role in memory consolidation is unclear, REM sleep appears to promote insight-based problem-solving more than does non-REM sleep (Stickgold & Walker, 2004). Cai et al. (2009) found better repeat performance on the Remote Associations Test, a divergent verbal creativity task, when participants had an intervening nap with REM sleep, compared with an NREM-only nap, resting wakefulness, or no previous exposure to the task. The passage of time did benefit all participants' performance to some degree, suggesting an incubation process occurred in all the conditions. The performance of participants in the REM-sleep group was due to more than just non-interference, however, as the lesser-performing wakeful group spent the interval period in quiet isolation. From this set of data, it appears that participants in the REM-sleep group benefited from autonomous incubation.



In summary, there are distinct cognitive processes that underlie the development of creative ideas, namely *incubation* and *insight.* Autonomous incubation, where new ideas are generated unconsciously, is of particular interest for this research, because it is a process that could be related to sleep mentation, such as dreaming or memory consolidation. Prior research has demonstrated that sleep can facilitate insight and incubation for creative problem-solving tasks.

**Problem-solving versus Task Performance**

The sleep and creativity literature, as well as the creativity literature in general, has largely focused on *problem-solving*, rather than *task performance*. Although the two constructs are similar, there are some important differences. Problem-solving studies tend to use tasks that frame the goal as an explicit problem that requires a solution, or multiple solutions, such potential uses for a shoe, or ways of dealing with a socially difficult situation. The tasks often do not overtly call for creative thinking. A task performance study, in contrast, might use a problem-based task, but could also require the participant to produce some kind of creative work. Creative application is the primary requirement, but there may be a problem-solving aspect to a creative task, in that the participant must think about the best way to create the product. Granted, a problem-solving approach in creativity research has an advantage in that it can explore creative thinking in multiple domains, such as art, science, and commerce. Researching creative task performance, however, explores creative thinking in the forms and behaviours that it is most commonly understood and most commonly manifests. Based on these issues, I aimed to investigate sleep and creativity using measures of creative task performance.



## SPECIFIC OBJECTIVES/ HYPOTHESES

The research reviewed above generally suggests that sleep and dreaming are 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. The particularly vivid and complex nature of REM dreaming also suggests that this period is characterised by memory restructuring that is typical of autonomous incubation, if not basic memory consolidation. The data from decision-making studies suggest that incubation probably facilitates the divergent aspects of creativity, but not the convergent aspects. 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, to investigate the relationship between sleep and creativity that goes beyond its application to problem-solving. The scarcity of research in the literature regarding sleep and creative task 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 warrants further investigation. The results of Wagner et al. (2004) suggest a causal relationship between sleep and insight that enhances task performance. For that study, however, a learned procedure was the main criterion for successfully completing the non-creative task. Cai et al. (2009) provide the most persuasive evidence yet that sleep, particularly REM sleep, facilitates divergent thinking, but their data showed superior performance with sleeping incubation on a verbal problem-solving task, rather than a naturalistic creative task.



In comparison to creative problem-solving, the cognitive processes underlying creative task performance are not well-understood. This contrast is even greater for the association between sleep and creativity. Further research is required to assess the benefits of sleep for performance on tasks that explicitly demand creative thinking.

Therefore, with respect to creative task performance, these specific hypotheses were tested in the current study:

- $H_1$: participants with an interval of normal nocturnal sleep between preparation and execution of the task will perform better on divergent thinking than participants with an interval of daytime wakefulness between preparation and execution.
- $H_2$: participants with an interval of normal nocturnal sleep between preparation and execution of the task will perform better on divergent thinking than participants with an interval of REM-deprived nocturnal sleep between preparation and execution.
- $H_3$: participants with an interval of daytime wakefulness between preparation and execution of the task will perform better on divergent thinking than participants with

no interval between preparation and execution.

- $H_4$: there will be no difference between participants on convergent thinking regardless of the nature of the interval between preparation and execution of the task.

In summary, for divergent thinking: normal SLEEP > WAKE interval; normal SLEEP > REM-deprived sleep; WAKE interval > awake NO-INTERVAL. With regard to convergent thinking: normal SLEEP = WAKE interval = REM-deprived sleep = awake NO-INTERVAL.

## DESIGN AND METHODOLOGY

The study was a 4-level, single-factor experimental design with state of consciousness as the manipulated variable. The main portion of the study was conducted over two sessions separated by an interval period. The experimental groups (SLEEP and REM) had a period of sleep during the experiment, while one control group (WAKE) had a roughly equivalent period of waking activity and a second control group (NO-INT) had no interval between the experimental sessions.

Creativity performance was measured by three approaches. Firstly, divergent cognition in verbal creativity was examined in terms of *fluency* (number of responses), *originality* (infrequency of particular responses in entire sample), and *flexibility* (number of shifts between types of response); these constructs are commonly used in creativity research (e.g., Carson et al., 2005; Krampen, 1997; Runco, Dow, & Smith, 2006). The dependent variable, performance on the creative task, was thus operationalised for the first stage of data analysis as three separate measures: Fluency, Flexibility and Originality. The benefit of these operationalisations was that they provided a relatively objective approach to assessing the creativity of the participants' performance.

The second stage of analysis used multiple, independent, subjective appraisals of creative performance in terms of Divergent and Convergent attributes, as defined by Brophy (2000; see Data Analysis subsection for more details). Thus, for the second approach, the dependent variable was operationalised as two separate general measures of creative performance.

The third stage of data analysis examined visual creativity using a separate task. The dependent variable, operationalised as performance on this task was measured as Design Fluency, by counting the number of appropriate responses.

**Participants**

I recruited 87 adult (18-30 years) participants, almost all from the undergraduate population at the University of Cape Town. Males and females were distributed equally between groups, as far as was feasible, to control for potential sex differences in creative ability. The participants were assigned to groups semi-randomly. The SLEEP and REM group participants were recruited as a single bloc and were later randomly assigned to either group. The WAKE and NO-INT groups were recruited separately and at different times from each other and from the experimental groups. This recruiting strategy made it less likely that potential volunteers would self-select between the WAKE and NO-INT groups, a real possibility given the different time commitments that the control groups required.



All aspects of the experiment were conducted in English. Because UCT is an English-language institution, with at least basic English proficiency as one of the entrance requirements, none of the participants' performances were negatively affected by the language component of the experimental protocol. Nonetheless, scores on a verbal intelligence test were used to control for variations in language competence.

**Materials and Apparatus**

The *Creative Achievement Questionnaire* (*CAQ*; Carson, Peterson, & Higgens, 2005) was used to assess participants' baseline creative ability. This scale, reproduced in Appendix B, is a self-report measure that assesses prior achievements in 10 creative domains: visual arts, music, dance, drama, architecture, humour, scientific discovery, invention and culinary. The instrument's developers report that it has good test-retest reliability (*r* = .81) and internal consistency ($\alpha$ = .96). The measure also has convergent validity with other measures of creative ability, as well as discriminant validity with IQ, and is also resistant to self-serving bias (Carson et al., 2005). The main advantages of using the CAQ in this study were that it was quick to administer and could be scored objectively.

The verbal edition of the *Torrance Test of Creative Thinking* (*TTCT*; Torrance, 2008a) was also used to assess participants' baseline creative ability. This instrument uses six word-based exercises to measure ability in Fluency, Flexibility and Originality. The TTCT is a well-established creativity measure that has been used successfully in past research (e.g., Chávez-Eakle, 2007; Healy & Runco, 2006; Kaufmann & Sternberg, 2007; Krampen, 1997). The TTCT has good psychometric properties; for instance, even untrained raters typically obtain high inter-rater reliability *r* coefficients (Fluency = .99; Flexibility = .95; Originality =.91; Torrance, 2008b)

Intelligence has been partially associated with creative ability (Vincent et al., 2002), thus the *Shipley Institute of Living Scale* (*SILS*; Shipley, 1940) was used to estimate participants' Verbal IQ levels and to thus control for the effect of existing English language competence. The SILS, shown in Appendix C, consists of two parts. Part 1 tests vocabulary by asking respondents to select the correct synonyms for target words. Part 2 tests logical reasoning by asking respondents to complete sequences with the correct letters or numbers. The raw scores from this test were used, as the sample was homogeneous 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 Wechsler intelligence test, with correlations ranging from *r* = .73 to .90 (Zachary, Crumpton, & Spiegel, 1985).

The experimental task for verbal creativity used an edited word list (see Appendix D) drawn from the Rey Verbal Learning Task lists, used to test memory and recognition in clinical neuropsychology (Crawford, Steward, & Moore, 1989). The word list consisted of 24 common nouns, mostly concrete and imagery-rich to facilitate retention. The authors of the original list established that semantic connections exist between some words on the complete list. Consequently, words were selected to ensure the edited list contained 12 semantically-related pairs. The participants memorised the list and later used it to write creative short stories.

The experimental task for visual creativity was the Four-Line Condition subtest for the Design Fluency Test (see Appendix E for the adapted version), which is often used to test visual generativity in clinical neuropsychology (Strauss, Sherman, & Spreen, 2006). The test requires one to draw as many different, abstract, four-line designs as possible in 4 minutes. Although this test has somewhat low test-retest reliability ($r$ = .70, Strauss et al., 2006), this property was considered useful for the study, because it possibly made the participants' performance on the task more sensitive to the experimental manipulations.

For participants in the SLEEP and REM groups, a polysomnograph monitored electrophysiological activity while asleep. Nine electrodes are attached to the scalp for the electroencephalograph to detect REM-typical brain waves. Four electrodes are attached to the face to record eye movements (electro-oculograph) and two electrodes are attached to the face to record muscle tone (electro-myograph), while two electrodes are attached to the chest to record the participants' heart rate (electrocardiograph). These instruments were used to detect periods of REM sleep and were applied to participants in both experimental groups to ensure treatment consistency.



**Procedure**

The study was conducted at Vincent Pallotti Hospital's Sleep Clinic (SLEEP and REM Groups) and at the Applied Cognitive Science & Experimental Neuropsychology Team (ACSENT) laboratory, a facility furnished with various forms of electronic equipment, computer software and neuropsychological tests in the Department of Psychology at UCT (WAKE Group and NO-INT groups). The procedure comprised experimental Session 1, an Interval Period, experimental Session 2, and a follow-up session.

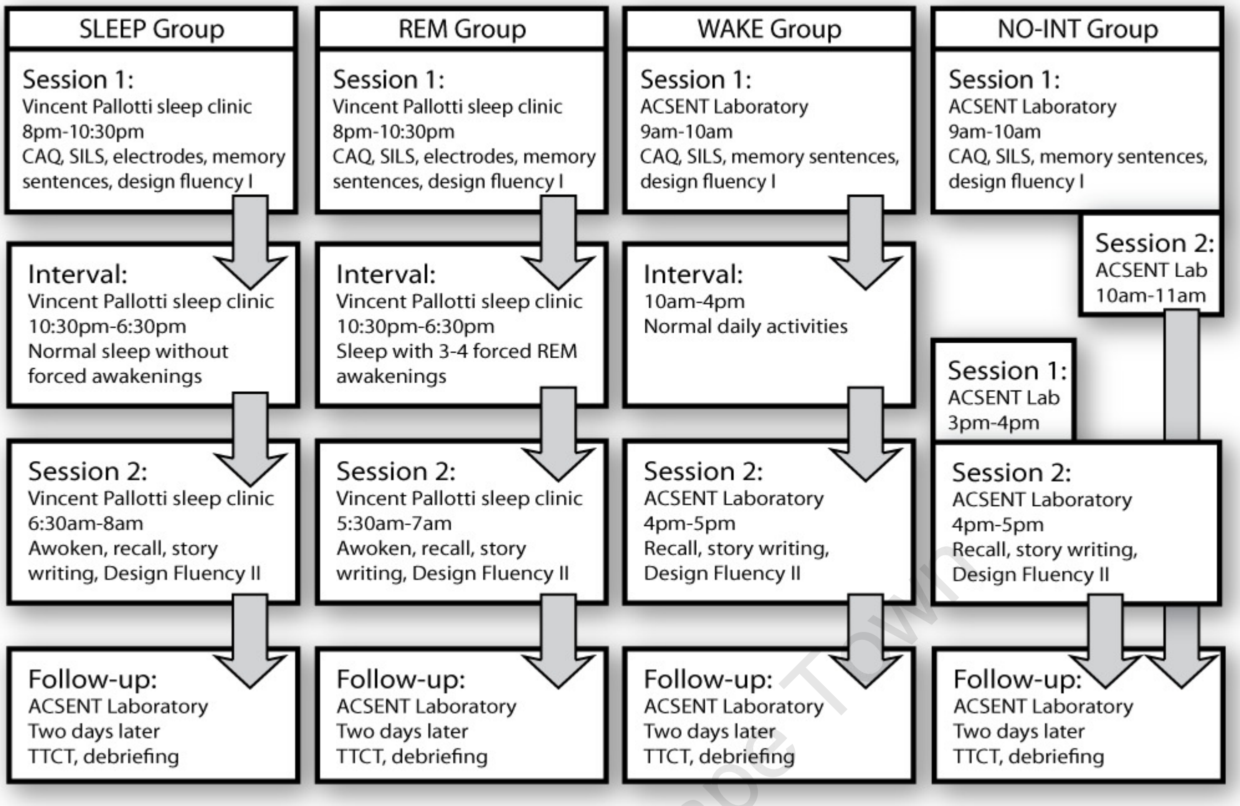


*Figure 1.* Summary of the experimental procedure

*Note:* Interval start and end times were approximate for the SLEEP and REM groups, as they depended on participants' time of sleep onset.



**Session 1.**

For participants in the SLEEP and REM groups, Session 1 occurred in the evening, when they arrived at the clinic at 8pm. In contrast, the WAKE Group performed Session 1 during the morning (at about 9am). Participants in the NO-INT group completed their sessions either in the morning (at about 9am) or in the afternoon (at about 3pm). Half of the participants in the latter group completed their Session 1 at 9am, whereas the other half completed their session at 3pm to control for time-of-day effects.

Participants in the SLEEP and REM groups were requested to not consume any alcohol 24 hours before Session 1, nor to consume any caffeine 6 hours beforehand, as these substances interfere with sleep quality (Esposito et al., 2004).

At the beginning of this experimental session, participants were briefed on all necessary details and received general instructions, after which they signed a consent form (see Appendix F) to confirm participation. They then completed the CAQ and the SILS. Participants in the SLEEP and REM groups then prepared for sleep, before the electrodes are attached to them. The electrodes were attached at this time to give the participants adequate time to habituate themselves to the potentially uncomfortable equipment.

At this stage of the session, participants in all groups received the word list. The experimenter instructed them to spend 15 minutes memorising it because it would be used for an unspecified task at the next session. To help them remember the list, they were asked 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. After the sentence task was completed, the Design Fluency task was administered. Session 1 ended at this point. Session 1 was structured to ensure that the memorisation period ended as close as possible to sleep-onset for the SLEEP and REM groups.[4]



Participants in the REM group were informed before sleep onset that they would be awoken several times during the night. The polysomnograph data were monitored during the course of the night and when participants in this group demonstrated clear signs of REM sleep for a continuous period of at least 5 minutes, they were awoken. At the beginning of these awakenings, the participants were asked to relate any sleep mentation, including dreaming, they might have experienced before regaining consciousness. In addition, they were given

[4] Although participants in sleep research usually spend at least one adaptation night in a sleep laboratory before the night of actual data collection (e.g., Cipolli et al., 1998), this procedure was not logistically feasible for this research. The absence of an adaptation night did not present a problem, however, as the experimental conditions are significantly different to the control conditions to suggest that small effects on sleep quality would not confound the results. Furthermore, the polysomnographic data gathered shows that participants had normal sleep architecture, with REM stage onset almost always occurring close to the predicted times.

digit span tests for up to 5 minutes. The results of the tests and the reports of sleep mentation were not utilised for data analysis. Rather, the objective was to ensure that the participants achieved a reasonably alert state of consciousness, so they would not continue in REM immediately when they returned to sleep. Participants were not awoken for the first REM stage, as this typically lasts no more than a few minutes (Zillmer, Spiers, & Culbertson, 2008). Therefore, REM group participants were awoken 3 or 4 times in the course of the night. SLEEP group participants were not awoken during the night.

**Interval.**

Participants in SLEEP, REM, and WAKE groups had an interval between the end of Session 1 and the beginning of Session 2, but whereas the SLEEP and REM groups spent that period asleep in the clinic during the night, participants in the WAKE Group completed their normal daytime activities. 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. The NO-INT group, of course, had no interval between sessions, commencing Session 2 immediately after completing Session 1 (although they were offered a 5-minute break between sessions).



**Session 2.**

This experimental session occurred in the morning after awakening for the SLEEP group (i.e., 8 hours from sleep onset), in the afternoon for the WAKE group (i.e., at about 4pm, 7 hours from the end of their Session 1), and no more than 5 minutes after Session 1 for the NO-INT group. The REM group also had Session 2 in the morning after awakening, but they were awoken 7 hours from sleep onset to eliminate the REM-dominant period that usually occurs in late sleep (Cipolli et al., 1998). Although the interval lengths differed between groups, this difference was not considered significant enough to introduce a confounding effect in the study. Previous research has found no effect for length of sleep on divergent task performance (Cai et al., 2009). To ensure that the SLEEP and REM group participants had time to regain consciousness fully before completing the tasks, the electrodes were removed after they awoke and the participants were offered an opportunity to refresh themselves.

In Session 2, all participants were first asked to write down as many words from the previously presented list as they could recall. Next, they were presented with 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. They were given half an hour to complete the task. The final task for Session 2 was the second trial of the Design Fluency test.

**Follow-up session.**

All participants returned for a follow-up session 2 days after Session 2 to complete the Verbal TTCT. The TTCT was administered after the experiment as its obviously creative content might have prematurely revealed the study's objective if it had it been administered before. Furthermore, carryover effects from the period of sleep, or the creative writing task, might have influenced the TTCT results if the test had been administered immediately after Session 2.

At the completion of this follow-up session, which lasted approximately 45 minutes, the participants were debriefed and compensated for their travelling expenses.

## Data Reduction and Statistical Analysis

The participants' generated sentences for the memorisation task and the stories were typed onto a computer and each piece of text, like the other experimental tasks, was identified by a unique code, recorded separately to the participants' demographic and group information. This procedure was followed to ensure participant anonymity and to reduce the possibility of bias occurring during the analysis. The spelling and grammatical errors of the original texts were retained in the typed versions.

The TTCT was scored blind by the experimenter and with the assistance of an independent scorer. The CAQ and SILS were scored by the experimenter but the response format did not require any interpretation and therefore the possibility of bias was low for these measures.

Apart from baseline creativity and verbal intelligence, a few other potential covariates were identified and measured. The degree to which participants effectively encoded the wordlist might have influenced the effectiveness of any incubation occurring during the interval; therefore Recall was defined as the number of list-words the participants remembered at the beginning of Session 2. Word Count was defined as the total number of words in the story.

The participants' verbal creative performance on the story-writing task was measured in two ways. Firstly, each participant's story was assessed using content analysis. This analysis utilised Carson et al.'s (2005) basic framework, with a scoring system specially devised for this study (see Appendix G for a worked example). More specifically, three scores were derived: Fluency, Originality, and Flexibility.

To derive a *Fluency* score, the number of list-words occurring in the story was counted, and the proportion of list-words used was calculated. The word-processor's Find function was utilised to facilitate an efficient and reliable search through the stories, supported by a manual search to include list-words that were misspelled. Fluency was then calculated by multiplying the total frequency of list-words by the proportion of list-words used. For example, if a participant's story contained 40 list-words and he used 18 of the 24 words from the list, his Fluency score would be 40 * (18 / 24) = 30.

To derive an *Originality* score, the number of unique non-list words (nouns and noun plurals only) within each participant's story was counted; this measure assessed the new ideas the participant added to the task. Close synonyms of list-words, such as *home* for *house,* were not included. Again, the word-processor's Find function was used to check that potential words did not occur in any of the other stories in the sample; again, a random manual search was used to take spelling errors into account. Where applicable, word roots were used in the search to include all permutations of the words.

To derive a *Flexibility* score, the number of pairs of unconventional semantic associations was counted. Apart from the semantic pairs originally identified in the RVLT, additional conventional semantic associations were identified that participants might use and were therefore excluded from the eligible unconventional pairs. These additional pairs were based on compound words commonly found in dictionaries, such as *water-bird* or *moonflower*. Three list-words, *sailor, captain,* and *teacher,* were also excluded, because participants tended to use these words as the protagonists of the stories, thus creating ambiguities with the pronouns that occurred in almost every sentence. The pairs were identified in the story by analysing the proximity between list-words. Legitimate pairs were counted where two non-related list-words occurred in the same or adjacent clause. Clauses separated by paragraph breaks were not counted. For example “The *bird* made a *nest* in the *helmet*. The man could not put the *helmet* on his *head,* so he went into the *house* instead.” gives bird/helmet, nest/helmet, nest/head, bird/head, house/head, and house/helmet as unconventional pairs; therefore this participant attained a Flexibility score of 6. A higher frequency of unconventional rather than conventional associations was assumed to reflect greater creative processing on the task.



For the second measure of verbal creative performance, four postgraduate English students were recruited as independent expert judges to give blind ratings of the stories and memorisation sentences. The stories and sentences were relabelled with non-numerical codes to prevent the raters from making assumptions about rank. Each rater received a pack with the texts arranged in a different random order (see Appendix H for the instructions to independent judges). Each story and collection of memory sentences received a score for divergent attributes (e.g., imaginativeness, originality, novelty, unconventionality – labelled Story Divergent) and convergent attributes (e.g., logic, plausibility, cohesiveness, structure – labelled as Story Convergent). These measures provided an alternative to the deconstructive, content-analytical technique outlined above, as they represented subjective assessments of the stories as a whole and the degree to which the elements of the story interact. The independent measures were also useful in determining the construct validity of the content analysis approach. The memory sentences were included in the independent assessment to obtain baseline measures of the participants' performance, in case there was significant covariance with their post-intervention performances (labelled as Sentence Convergent and Sentence Divergent).

The Design Fluency drawings were scored in the original manner specified by the test authors, by another independent rater. More specifically, that rater counted, for each participant on each trial, all the drawings that matched the instructions given to the participants. Each participant therefore initially received two scores for this measure, one for each trial. A relative increase value from the first to the second trial was computed using this formula: $(Trial_2 – Trial_1) / Trial_1$. For example, if the participant scored 16 on the first trial and 25 on the second trial, his overall Design Fluency score would be (25 – 16) / 16 = .563. This score represents the participant's improvement on the task, which would be theoretically influenced by the type of interval period the participant experienced, while simultaneously controlling for baseline performance.



# RESULTS

## Statistical Analyses

The data were checked to ensure that they met the assumptions for parametric statistical tests; more specifically, I ran Levene's test to check for homogeneity of variance, and inspected probability plots to ensure the data were normally distributed. Descriptive statistics were obtained for all potential covariates. All potential covariates (Age, CAQ score, TTCT score, List Recall score, story Word Count, Sentence Divergent rating, and Sentence Convergent rating) were tested using one-way analysis of variance (ANOVA) to check for statistically significant between-group differences that might have obscured the group performances on the creative tasks. The data for the outcome variables were also checked for the same assumptions for parametric statistical tests as the data for the potential covariates. Based on the results of the potential covariate ANOVAs, one-way analysis of covariance tests (ANCOVAs) were conducted with the outcome variables. For significant ANOVA and ANCOVA results, post-hoc Tukey's HSD comparisons were conducted. Only post-hoc comparisons relevant to the experimental hypotheses were used: for divergent measures SLEEP > WAKE, SLEEP > REM, WAKE > NO-INT, and for convergent measures SLEEP = WAKE = REM = NO-INT.

The outcome variable analyses are grouped in this section according to the experimental tasks: content analysis (Fluency, Flexibility, and Originality) and independent ratings for the creative writing task (Story Divergent and Story Convergent), and design fluency for the visual creativity task. Group performances on all of the outcome measures were used to test the predictions of SLEEP > WAKE, SLEEP > REM, and WAKE > NO-INT, except for the Story Convergent measure, which tested SLEEP = WAKE = REM = NO-INT. Following the ANOVAs, Fisher's *r* to *z* transformations were used to compare the within-group correlations between each dependent variable and scores on the Torrance Test of Creative Thinking, to examine the interactive relationship between creative aptitude and the experimental manipulations.

The statistical significance level was set at $\alpha = 0.05$ for all tests. All statistical analyses were completed using Statistica 8 (Statsoft, 2008).

**Testing Assumptions Underlying Parametric Statistical Tests**

All the potential covariates were non-significant for Levene's test (see Table 1) indicating that there was homogeneity of variance in all cases. Examination of the probability plots (see Appendix A, Figures A1-A8) for the covariate data suggested that the samples were normally distributed. Furthermore, all measures were taken from independent observations. Thus, the covariate data meet the assumptions for one-way ANOVA.

Table 1

*ANOVA Summaries and Levene's* p-*values for Potential Covariates*

| Covariate variable | *Levene's p* | *df* | *F* | *p* |
|---|---|---|---|---|
| Age | 0.147 | 3, 60 | 1.781 | 0.160 |
| CAQ | 0.398 | 3, 82 | 0.510 | 0.676 |
| SILS | 0.854 | 3, 83 | 0.287 | 0.835 |
| TTCT | 0.406 | 3, 60 | 1.371 | 0.260 |
| List Recall | 0.608 | 3, 82 | 0.855 | 0.468 |
| Word Count | 0.119 | 3, 83 | 1.517 | 0.216 |
| Sentence Divergent | 0.259 | 3, 83 | 2.172 | 0.097 |
| Sentence Convergent | 0.187 | 3, 83 | 4.927 | 0.003 |

*Note.* CAQ: Creative Achievement Questionnaire; SILS: Shipley Institute of Living Scale; TTCT: Torrance Test of Creative Thinking, Verbal Form A.



Unlike the covariates, the assumptions tests for the dependent variables produced mixed results. While the scores for Story Divergent, Story Convergent, Fluency, and Flexibility gave non-significant *p*-values for Levene's test (see Table 2), the scores for Originality and Design Fluency did have significant *p*-values, indicating that the variances were not homogeneous for those two measures. The probability plots for the dependent variables show that the data were generally normally distributed (see Figures A9-A12 and A13). The plots for Originality and Design Fluency (Figures A11 A14), however, do show some noticeable deviations from expected values in a few cases. ANCOVA is considered robust to violations of these two assumptions, however. All the dependent measures were also taken from independent samples. Thus, the dependent variable data broadly meet the requirements for one-way ANCOVA.

Table 2

*Significance Values for Levene's Test of Homogeneity of Variance*

| Outcome variable | *Levene's p* |
|---|---|
| Fluency | 0.917 |
| Flexibility | 0.920 |
| Originality | < .001 |
| Story Divergent | 0.426 |
| Story Convergent | 0.933 |
| Design Fluency | 0.031 |

**Analyses of Potential Covariates**

Table 3 presents descriptive statistics for the potential covariates. The mean TTCT scores were slightly above the norms reported by Torrance (2008b) for the age groups in this study (normative mean for 18yrs = 101.3; 19yrs = 101.9; 20yrs+ = 102.0), although the standard deviations were similar (normative SD for 18yrs = 16.3; 19yrs = 15.6; 20yrs+ = 18.7) Furthermore, participants generally ranked between the 50$^{th}$ and 75$^{th}$ percentiles relative to the standardization group, suggesting that they were average to above-average for baseline creativity. Only one of the potential covariates, Sentence Convergent, showed a statistically significant between-group difference (see Table 1). As shown in Table 3, raters awarded participants in the WAKE group significantly higher scores than they did to participants in the sleeping interval groups (vs. SLEEP: $p = .019$; vs. REM: $p = .004$). Based on this set of results, the variable Sentence Convergent was used as a covariate in subsequent ANCOVAs for the dependent variables Fluency, Flexibility, Originality, Story Divergent, and Story Convergent.

Table 3

*Descriptive Statistics for Potential Covariates*

| Covariate | Group | *n* | Mean | SD |
|---|---|---|---|---|
| Age | WAKE | 24 | 20.08 | 1.67 |
| | SLEEP | 24 | 20.50 | 2.04 |
| | REM | 19 | 21.26 | 2.84 |
| | NO-INT | 20 | 21.80 | 2.61 |
| | Total | 87 | 20.85 | 2.35 |
| CAQ | WAKE | 24 | 9.58 | 6.04 |
| | SLEEP | 24 | 11.42 | 8.72 |
| | REM | 18 | 8.72 | 5.81 |
| | NO-INT | 20 | 10.20 | 8.10 |
| | Total | 86 | 10.06 | 7.27 |
| SILS | WAKE | 24 | 46.71 | 5.58 |
| | SLEEP | 24 | 46.67 | 6.28 |
| | REM | 19 | 45.68 | 6.73 |
| | NO-INT | 20 | 45.35 | 5.28 |
| | Total | 87 | 46.16 | 5.91 |
| TTCT | WAKE | 16 | 104.02 | 17.54 |
| | SLEEP | 16 | 112.13 | 13.72 |
| | REM | 16 | 113.52 | 15.89 |
| | NO-INT | 16 | 114.96 | 19.25 |
| | Total | 64 | 111.16 | 16.87 |
| Recall | WAKE | 24 | 18.67 | 5.05 |
| | SLEEP | 24 | 18.42 | 4.63 |
| | REM | 18 | 20.06 | 3.86 |
| | NO-INT | 20 | 20.15 | 4.30 |
| | Total | 86 | 18.67 | 5.05 |
| Word Count | WAKE | 24 | 286.08 | 118.51 |
| | SLEEP | 24 | 275.08 | 138.36 |
| | REM | 19 | 254.16 | 94.82 |

| | | | | |
|---|---|---|---|---|
| | NO-INT | 20 | 218.00 | 81.75 |
| | Total | 87 | 260.43 | 113.60 |
| Memory Sentence Divergent Score | WAKE | 24 | 39.43 | 11.84 |
| | SLEEP | 24 | 37.71 | 9.98 |
| | REM | 19 | 33.22 | 7.82 |
| | NO-INT | 20 | 32.85 | 10.88 |
| | Total | 87 | 36.09 | 10.55 |
| Memory Sentence Convergent Score | WAKE | 24 | 41.30 | 10.57 |
| | SLEEP | 24 | 34.18 | 7.26 |
| | REM | 19 | 32.42 | 6.59 |
| | NO-INT | 20 | 35.35 | 7.55 |
| | Total | 87 | 36.03 | 8.80 |

Sentence Convergent was not used as a covariate when doing a between-group analysis on the Design Fluency data. This is because the Design Fluency task operates in a visual modality, unlike the other creative tasks used in the study. The Design Fluency test also primarily assesses divergent cognition, with a minimal contribution from convergent processes. The Sentence Convergent scores were therefore not considered relevant in this instance. Furthermore, there was a very weak, non-significant, correlation between Design Fluency and Sentence Convergent ($r$ = .09), confirming there was little connection between the variables. Hence, the between-group comparison of performance on the Design Fluency measure was run as a one-way ANOVA.

**Content Analysis**

A statistically significant result was obtained for the Fluency scores (see Table 4, Figure 2); however, the trend was the inverse of what was expected. The NO-INT group performed the best on this measure, while the SLEEP group had the lowest score. Three post-hoc Tukey's HSD comparisons were conducted to test the experimental hypotheses, but no significant results were obtained ($H_1$: $p$ = .285; $H_2$: $p$ = .999; $H_3$: $p$ = .997), suggesting that only the overall trend was significant, or that other between-group differences contributed to the significant result. The effect size for the Fluency result was small (adjusted $r^2$ = .11; partial $\varepsilon^2$ = .102).

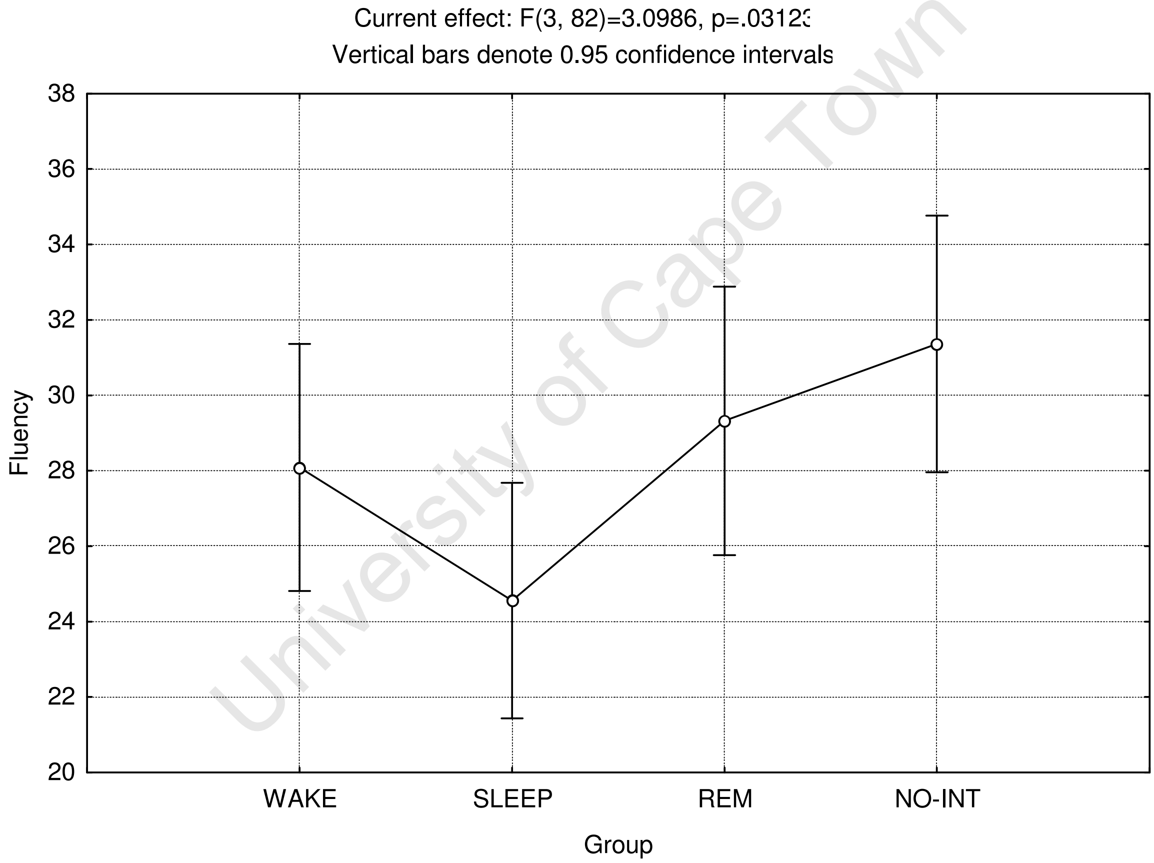


*Figure 2.* Cell mean plot for Fluency

Table 4

*Descriptive Statistics and ANCOVA Summary for Fluency*

| Group | *n* | Mean | SD | Adjusted Mean | *df* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| WAKE | 24 | 29.16 | 8.07 | 28.04 | | | |
| SLEEP | 24 | 24.18 | 7.73 | 24.51 | | | |
| REM | 19 | 28.59 | 7.61 | 29.28 | | | |
| NO-INT | 20 | 31.22 | 7.61 | 31.32 | | | |
| Total | 87 | 28.14 | 8.08 | | | | |
| Sentence Convergent | | | | | 1 | 3.995 | 0.049 |
| Fluency | | | | | 3, 82 | 3.099 | 0.031 |



A non-significant result was obtained for the Flexibility measures ($p$ = .188) and again the trend was the inverse of what was expected (see Figure 3 and Table 5). Specifically, the NO-INT group performed the best on this measure, while the SLEEP group had the lowest score.

Table 5

*Descriptive Statistics and ANCOVA Summary for Flexibility*

| Group | *n* | Mean | SD | Adjusted Mean | *df* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| WAKE | 24 | 11.63 | 5.93 | 11.89 | | | |
| SLEEP | 24 | 11.04 | 5.29 | 10.96 | | | |
| REM | 19 | 12.16 | 6.34 | 12.00 | | | |
| NO-INT | 20 | 14.90 | 6.79 | 14.88 | | | |
| Total | 87 | 12.33 | 6.14 | | | | |
| Sentence Convergent | | | | | 1 | 0.344 | 0.559 |
| Flexibility | | | | | 3, 82 | 1.631 | 0.188 |

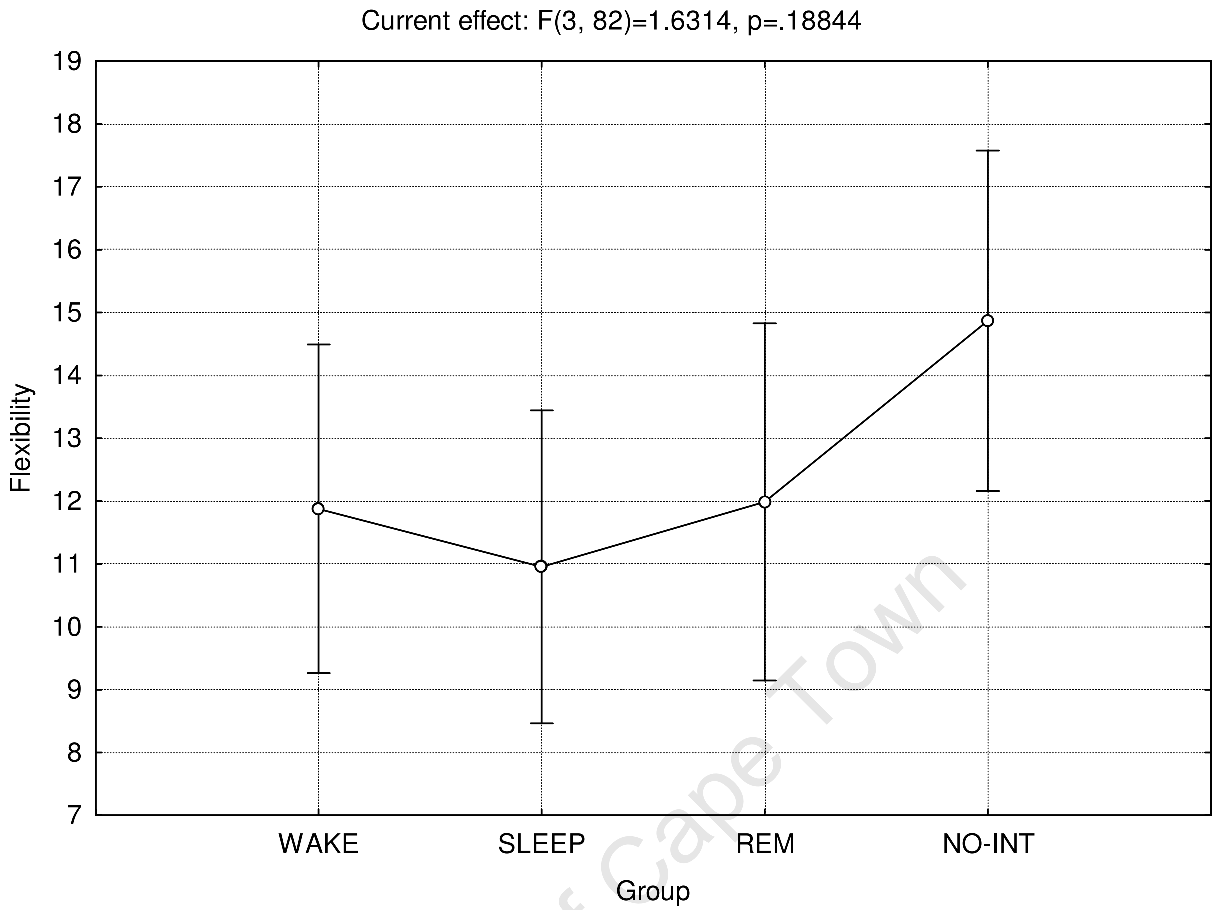


*Figure 3.* Cell mean plot for Flexibility



Although a non-significant result was also obtained for the Originality outcome variable ($p$ = .135), the trend did follow the expected pattern (Table 6, Figure 4). As shown in Table 6, the SLEEP group had the highest mean score, outperforming the WAKE and REM groups. On average, participants in the WAKE group did better on this measure than did participants in the NO-INT group. Of course, these differences were too small to be statistically significant.

Table 6

*Descriptive Statistics and ANCOVA Summary for Originality*

| Group | *n* | Mean | SD | Adjusted Mean | *df* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| WAKE | 24 | 5.33 | 3.82 | 5.92 | | | |
| SLEEP | 24 | 7.21 | 7.06 | 7.03 | | | |
| REM | 19 | 4.63 | 2.91 | 4.27 | | | |
| NO-INT | 20 | 4.05 | 4.17 | 4.00 | | | |
| Total | 87 | 5.40 | 4.93 | | | | |
| Sentence Convergent | | | | | 1 | 2.738 | 0.102 |
| Originality | | | | | 3, 82 | 1.905 | 0.135 |

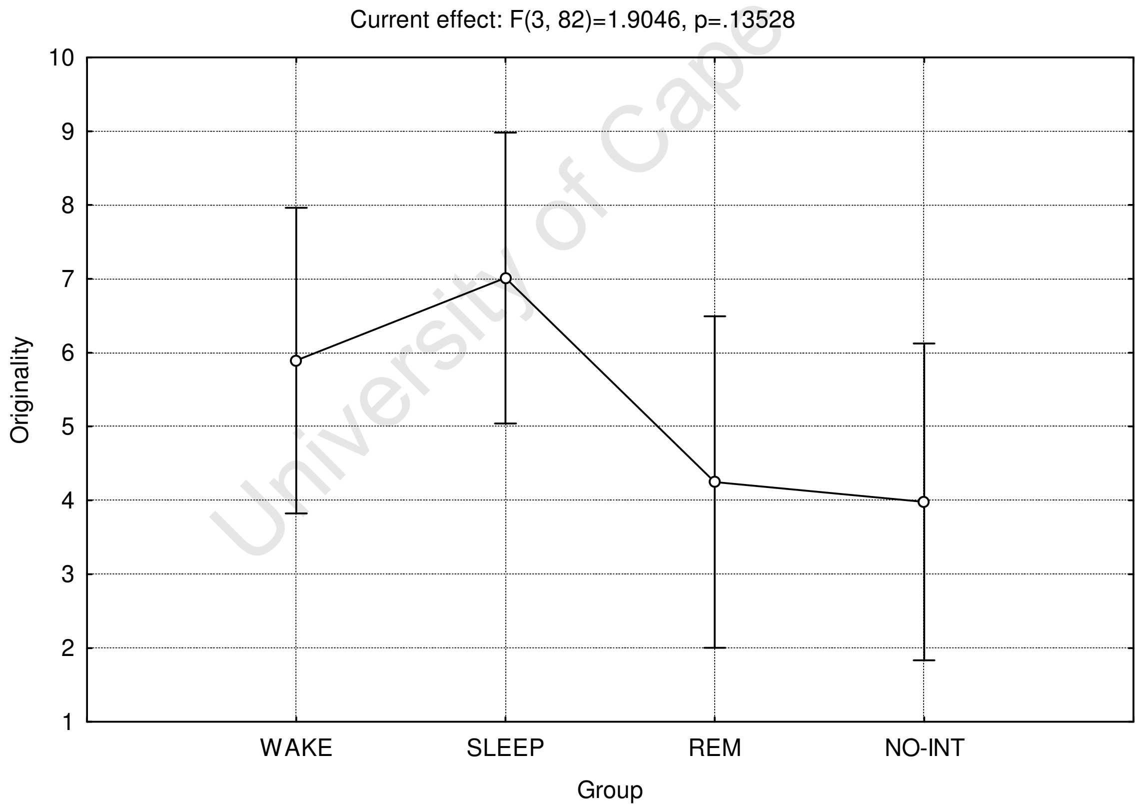


*Figure 4.* Cell mean plot for Originality

**Independent Ratings**

The four independent raters' scores were analysed to determine inter-rater reliability. A Kendall coefficient of concordance of .261 was derived. This level is somewhat low, so the results obtained from the independent raters should be treated with caution.

A non-significant result for the Story Divergent outcome variable was obtained and the trend was different from the content analysis results (Table 7, Figure 5). As Table 7 shows, although the WAKE group scored higher than the NO-INT group, the SLEEP and REM groups scored almost identically and lower than the WAKE group.

Table 7

*Descriptive Statistics and ANCOVA Summary for Story Divergent*

| Group | *n* | Mean | SD | Adjusted Mean | *df* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| WAKE | 24 | 64.93 | 10.56 | 64.43 | | | |
| SLEEP | 24 | 59.35 | 12.69 | 59.50 | | | |
| REM | 19 | 59.39 | 12.47 | 59.70 | | | |
| NO-INT | 20 | 57.28 | 9.27 | 57.32 | | | |
| Total | 87 | 60.42 | 11.53 | | | | |
| Sentence Convergent | | | | | 1 | 0.362 | 0.549 |
| Story Divergent | | | | | 3, 82 | 1.402 | 0.248 |

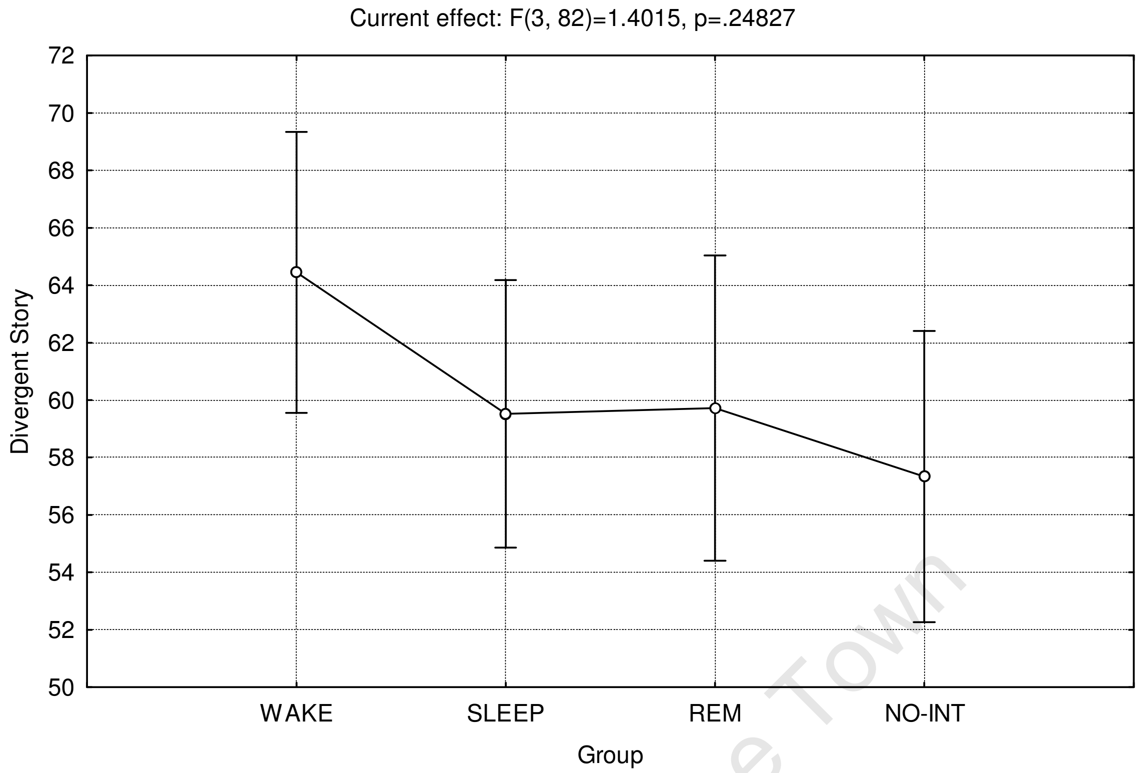


*Figure 5.* Cell mean plot for Divergent Story

In terms of the Story Convergent outcome variable, there were again no statistically significant between-groups differences. Furthermore, the trend here was again different from the other dependent variables (see Table 8, Figure 6). Specifically, the WAKE group performed better than the other groups, while the SLEEP group, with the lowest mean, had a similar score to the NO-INT group.

Table 8

*Descriptive Statistics and ANCOVA Summary for Story Convergent*

| Group | *n* | Mean | St. Dev. | Adjusted Mean | *df* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| WAKE | 24 | 60.32 | 12.49 | 60.41 | | | |
| SLEEP | 24 | 52.02 | 11.48 | 51.99 | | | |
| REM | 19 | 54.26 | 13.13 | 54.21 | | | |
| NO-INT | 20 | 52.94 | 12.65 | 52.93 | | | |
| Total | 87 | 55.01 | 12.64 | | | | |
| Sentence Convergent | | | | | 1 | 0.009 | 0.923 |
| Story Convergent | | | | | 3, 82 | 1.918 | 0.133 |

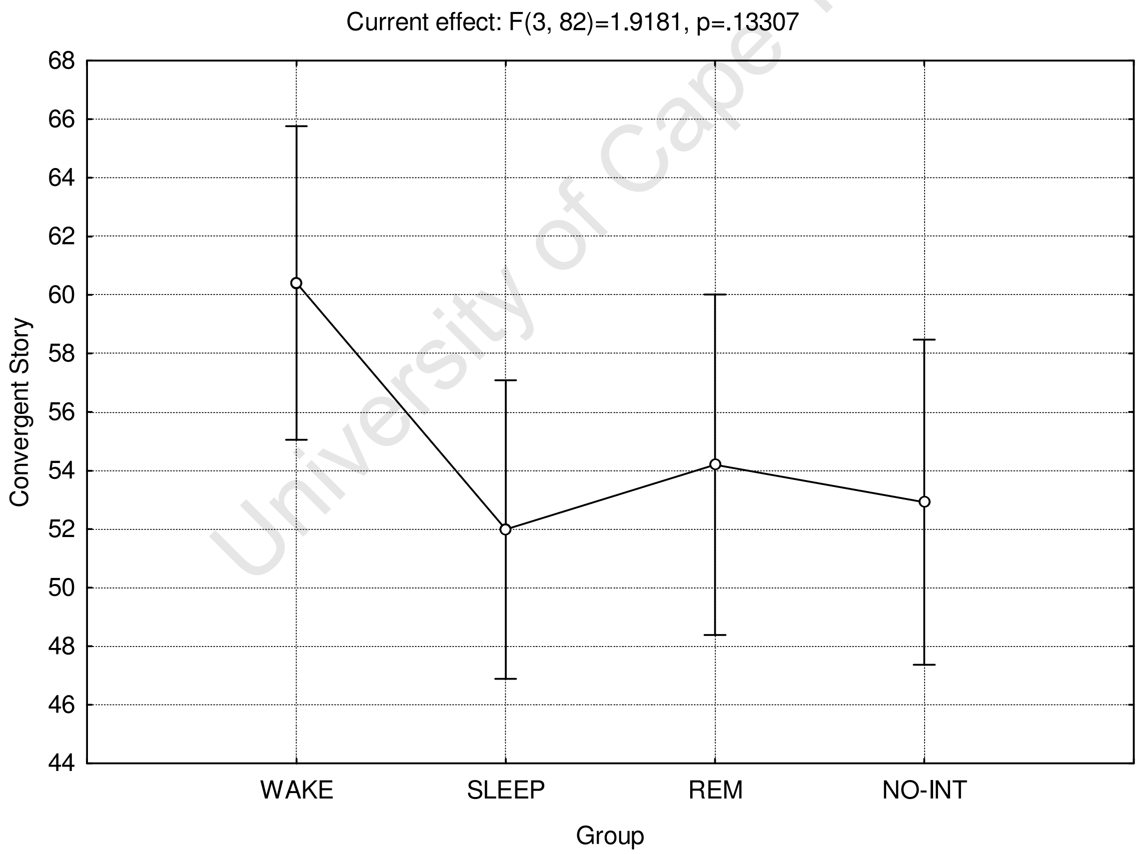


*Figure 6.* Cell mean plot for Story Convergent



Considering the mostly non-significant results obtained for the outcome measures analysed thus far, I tested the construct validity of the independent ratings in relation to the outcome measures derived from the content analyses. The independent judges assessed the general properties of the stories in terms of divergent and convergent thinking, while the content analysis quantified specific patterns of word-use in the story. Although the measurement approaches were different, they were intended to measure the same underlying construct, which is divergent thinking. If Fluency, Flexibility, and Originality were true manifestations of divergent thinking, as operationalised in this study, then the scores for those measures should have been similar to the Story Divergent scores given by the independent judges. This is *convergent validity* and would be demonstrated by positive correlations between the outcome measures. In contrast, if divergent thinking is truly different from convergent thinking, then the measures of each cognition type should yield different, even inverse, scores. This is *discriminant validity* and would be demonstrated by negative correlations between the different outcome measures. Specifically Fluency, Flexibility, and Originality should correlate negatively with the Story Convergent outcome measure. In short, the usefulness of the content analysis method of measuring divergent thinking in terms can be effectively assessed with measures of convergent and discriminant validity, because we can test that the outcome measures are a quantification of the correct construct.

To evaluate the convergent and discriminant validity of the content analysis approach to measuring creative performance, a series of Pearson's correlations were computed with the previous five dependent variables (See Table 9). The correlation with Story Divergent was weak and positive for Fluency, almost absent for Flexibility, and moderate and positive for Originality. The correlation with Story Convergent was almost absent for Fluency, moderately negative for Flexibility, and moderately negative for Originality. Of the three measures, interestingly, there was a moderate positive correlation between Story Divergent and Story Convergent.

Table 9

*Correlation Matrix of Dependent Variables for Verbal Creativity*

| | Story Divergent | Story Convergent | Fluency | Flexibility | Originality |
|---|---|---|---|---|---|
| Story Divergent | | .56* | .13 | -.03 | .47* |
| Story Convergent | .56* | | -.06 | -.40* | -.39* |
| Fluency | .13 | -.06 | | .49* | -.15 |
| Flexibility | -.03 | -.40 | .49* | | -.26* |
| Originality | .47* | -.39* | -.15 | -.26* | |

* $p < .05$



**Design Fluency**

In contrast to the mostly non-significant findings for the measures of verbal creativity, there was a statistically significant between-groups difference on the Design Fluency measure for visual creativity. The data did not follow the expected trend, however (see Table 10, Figure 7). Specifically, the WAKE group and the NO-INT performed similarly and better than the SLEEP and the REM groups, which had near-identical improvements across the trials. Post-hoc Tukey's comparisons were conducted to test the experimental hypotheses, but these were not significant ($H_1$ SLEEP > WAKE: $p = .117$; $H_2$ SLEEP > REM: $p = .245$; $H_3$ WAKE > NO-INT: $p = .809$). An inspection of the cell mean plot suggested that the significant difference might lie between the SLEEP and the NO-INT groups, which was confirmed by an additional Tukey's HSD test ($p = .016$). The effect size for the Design Fluency result was small (adjusted $r^2 = .09$; partial $\varepsilon^2 = .141$).

Table 10

*Descriptive Statistics and ANOVA Summary for Design Fluency*

| Group | *n* | Mean | SD | *df* | *F* | *p* |
|---|---|---|---|---|---|---|
| WAKE | 12 | 0.35 | 0.31 | | | |
| SLEEP | 12 | 0.06 | 0.27 | | | |
| REM | 12 | 0.06 | 0.17 | | | |
| NO-INT | 20 | 0.38 | 0.54 | | | |
| Total | 56 | 0.23 | 0.41 | | | |
| Design Fluency | | | | 3, 52 | 2.848 | 0.046 |

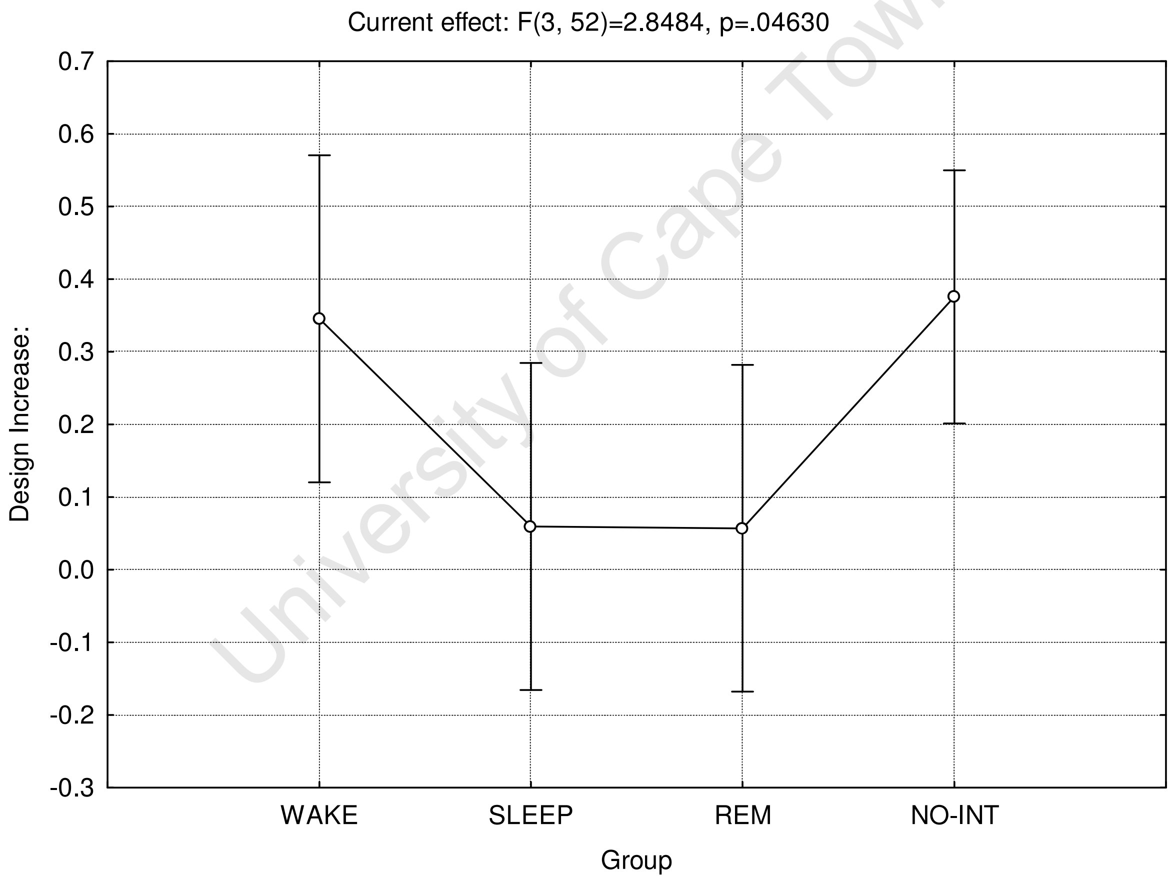


*Figure 7.* Cell mean plot for Design Fluency

**Baseline Creativity and Dependent Variable Performance**

Considering the mixed results obtained with the ANCOVAs, a deeper investigation of the data was conducted. As previous research (e.g., Domino, 1976; Healy & Runco, 2006) has shown, highly creative people have different sleeping pattern and dream characteristics from people with less creative aptitude. It is possible that baseline creativity led to different levels of performance on the creative task under the different conditions of this study.

Unfortunately, the data were not structured to facilitate a factorial ANOVA to test this alternate hypothesis, so the within-group correlations between the participants' TTCT scores and dependent variable scores were examined instead. The TTCT was selected as the best measure of baseline creativity, as it directly evaluates creative ability, unlike the CAQ, which is an indicator of past creative achievement. The TTCT also had better correlations with the groups' overall performance on the dependent measures (mean $r = .14$ vs. mean $r = .11$ for CAQ). The within-group coefficients were compared using Fisher's $r$ to $z$ transformation (see Table 10). Despite the low overall correlation with the TTCT, the within-group coefficients show noticeable variability. Only three comparisons for each dependent variable were conducted, however, to reduce the possibility of committing Type I errors. The comparisons were the same as the post-hoc Tukey's tests used with the significant ANCOVA results: those relevant to the experimental hypotheses.

Table 11

*Fisher's r to z Transformations: Selected Comparisons of Correlations between DVs and TTCT*

| Variable | Hypothesis | *r* | *z* | *p* |
|---|---|---|---|---|
| Fluency | SLEEP > WAKE | .41 - .19 | .62 | .268 |
| | SLEEP > REM | .41 - .33 | .24 | .405 |
| | WAKE > NO-INT | .19 - .30 | -.30 | .382 |
| Flexibility | SLEEP > WAKE | -.11 - .31 | -1.10 | .136 |
| | SLEEP > REM | -.11 - .49 | -1.65 | .049* |
| | WAKE > NO-INT | .31 - .16 | .70 | .242 |
| Originality | SLEEP > WAKE | .29 - .02 | .71 | .239 |
| | SLEEP > REM | .29 - (-.15) | 1.15 | .125 |
| | WAKE > NO-INT | .02 - (-.59) | 1.78 | .038* |
| Story Divergent | SLEEP > WAKE | .13 - .37 | -.66 | .255 |
| | SLEEP > REM | .13 - .36 | -.63 | .264 |
| | WAKE > NO-INT | .37 - .09 | .76 | .224 |
| Story Convergent | SLEEP > WAKE | .00 - .23 | -.60 | .274 |
| | SLEEP > REM | .00 - (-.30) | .78 | .218 |
| | WAKE > NO-INT | .23 - (-.08) | .80 | .212 |
| Design Fluency | SLEEP > WAKE | -.04 - (-.50) | 1.08 | .140 |
| | SLEEP > REM | -.04 - (-.02) | -.04 | .484 |
| | WAKE > NO-INT | -.50 - .32 | -2.03 | .021* |

*p < .05



Three statistically significant between-group differences were found. First, there was a significant difference between the REM and SLEEP groups for their Flexibility scores. The moderate positive correlation for the REM group ($r^2$ = .24) contrasted with the SLEEP group's very weak negative correlation ($r^2$ = .01). The SLEEP group also had slightly lower, but not significant, mean Flexibility scores. The REM group's baseline creativity was a weak predictor for their performance on Flexibility, but baseline creativity did not predict the SLEEP group's performance on this measure.

Second, the WAKE and NO-INT group were statistically significantly different for the correlation between TTCT and Originality scores. Although there was no correlation for the WAKE group, baseline creativity was moderately negatively correlated with Originality ($r^2$ = .35). The WAKE group performed slightly better on this measure than the NO-INT group, but not significantly so. While highly creative NO-INT participants performed poorly on Originality to a small extent, the WAKE participants' baseline creativity did not predict their performance on this measure.



Third, the WAKE and NO-INT groups were statistically significantly different for the correlation between TTCT and Design Fluency ($p$ = .021), but with the opposite pattern of results. The NO-INT group's performance was weakly correlated with baseline creativity ($r^2$ = .10) in contrast with the moderately negative correlation for the WAKE group ($r^2$ = .25). High baseline creativity could very weakly predict high Design Fluency for the NO-INT group, but weakly predict low Design Fluency for the WAKE group. The possible reasons for these patterns of results will be discussed further later in the manuscript.

## DISCUSSION

This study aimed to investigate the effect that sleep can have on creative task performance. Four groups were used in the study: an experimental group with a night-time interval of normal sleep (SLEEP), an experimental group with a night-time interval of REM-deprived sleep (REM), a control group with a daytime interval of waking consciousness (WAKE), and a daytime control group without an interval period (NO-INT). Participants were given a word list to memorise for the verbal creativity task, and the first trial of a design fluency test for the visual creativity task, at the pre-interval session. At the post-interval session, each participant wrote a creative short story, using the word list, and completed the second trial of the design fluency test. Participants' performance on the tasks was quantified using various outcome measures of divergent and convergent cognition, which comprise creative thinking. In terms of divergent cognition, the 3 hypotheses were: SLEEP > WAKE; SLEEP > REM; WAKE > NO- INT and in terms of convergent cognition, the hypothesis was SLEEP = REM = WAKE = NO-INT.

The outcome measures generally did not support the experimental hypotheses, especially if the data are interpreted according to the basic results. Put simply, there was no direct evidence that sleep, in comparison to waking consciousness, facilitates creative task performance. Nor was there direct evidence to show that REM sleep has a particular benefit for creative incubation. Furthermore, there was no evidence that interval periods where incubation could occur are useful for creativity. The only hypothesis that the data can confirm is that convergent cognition, which is generally regarded as being orthogonal to creativity, is unaffected by varying levels of consciousness during periods that precede creative task performance. The latter finding was expected because all the participants completed the creative task in a state of normal wakefulness. In terms of creativity theory, the writing task was the final stage of the creative process, when convergent processes should have predominated. The nature of the interval period did not appear to affect the participants' ability to engage in convergent thinking.



This finding needs to be interpreted with caution, however, because it is based on the statistically non-significant differences in independent ratings of convergent story attributes, which showed low inter-rater reliability. The ratings for divergent attributes of the stories were also non-significant, so it is possible that both measures were flawed. Despite the generally statistically non-significant findings, some interesting trends and patterns emerged from the data and warrant further discussion and investigation.

**Fluency and Originality**

The results relevant to these two outcome measures were more or less the inverse of each other, even though both are supposed to be measures of the same construct: divergent cognition. The reason for the inversion may lie with the operationalisations of Fluency and Originality. *Fluency* was defined as the number of list-words present in the story, adjusted according to the proportion of list-words used by the participant. *Originality* was defined as the number of nouns in the story that are unique in terms of the entire sample, which are therefore all non-list words. The total number of words in each story was largely similar in the sample and was not significantly different across the groups. Consequently, when participants used a high number of list words in their stories, there was a correspondingly smaller proportion of original words in the stories, and vice versa.[5] In short, Fluency and Originality operated as inverse constructs in this study.

Compared to participants in the SLEEP and REM groups, participants in the WAKE and NO-INT groups used more list-words and fewer original words, although the Originality score differences were not statistically significant. This pattern of data suggests that the sleeping-interval participants used more elaboration in their stories, possibly at the expense of following the task instructions to use as many of the list-words as possible. In contrast, the waking control groups stuck more closely to the task material that they were given. The interpretation of this pattern of data depends on how one defines creative task performance. For instance, if one focuses on novelty when defining creativity, then the sleeping interval participants appear more creative. On the other hand, if one focuses on providing an effective solution to a need, then the waking interval participants appear more creative. The usual division of divergent cognition into Fluency, Flexibility, and Originality presents an apparent contradiction for this data.

Although the participants were asked to use as many list-words as possible, they were not asked to use only list-words, or to base their stories on the list-words. For this reason, list-

[5] Of course, these two outcome measures do not account for all words in the stories. There were also other non-unique nouns, function words, adjectives and others.

word frequency might not be the best measure of Fluency. It is possible that *total* word counts would have been a better operationalisation of Fluency, as it would measure total output. That alternate approach would have ignored the significant differences in how the groups were using the test material, however, and it has already been established that there were no between-group differences in word count.

One could argue that omitting adjectives from the content analysis, except for list-words used as adjectives, may have also affected the results. The use of more adjectives might possibly create richer descriptions and more vivid narratives. Thus, greater adjective usage could reflect greater creativity. On the other hand, greater adjective usage could also simply reflect greater vocabulary (perhaps even more so than noun usage). Nonetheless, including the number of unique adjectives in the Originality score may have altered that score to the extent that statistically significant between-group differences would have been found.

Using nouns focused the content analysis on narrative elements of the story, such as characters and places, and also made the Fluency and Originality scores more comparable. Furthermore, the independent raters' divergent scores were also intended to capture the aspects of creativity that content analysis might not include. Thus, the narrow definitions for the content analysis measures should have not affected the results to a large extent, because alternate measures were also used.



The inverse trends observed in terms of Fluency and Originality scores might be less paradoxical if a different definition of creativity was used. For example, one could define creative task performance as producing novel work in response to particular task demands, which is not so different from the definition introduced at the beginning of this thesis. To some extent, the SLEEP and REM groups behaved more creatively than the WAKE and NO-INT groups: in creating their stories, they deviated further from the word list, despite the fact that this was not exactly what they were instructed to do. Originality also had the strongest positive correlation with the independent raters' Story Divergent scores and the strongest negative correlation with the raters' Story Convergent scores. Perhaps, then, Originality was the most important measure of creativity in this study, because it was the most pure measure of divergent cognition used. Future research could focus on originality as an index of elaboration in incubation[6].

**Flexibility**

Unlike the scores for Fluency and Originality, a less clear trend emerged for the Flexibility scores. As with the Fluency scores, in terms of Flexibility participants in the SLEEP group had poorer performance than those in the WAKE and REM groups; those in the NO-INT group had the best performance. The similarity to Fluency is understandable, because the Flexibility score was based on associations between list-words. Therefore, the more list-words that occurred in a story, the more likely semantically distant associations in list-words would be found in the story. The Flexibility measure was, in effect, was confounded by the Fluency measure.

To remedy this problem, Flexibility could be defined more broadly to include all semantic or ideational shifts in the story. This would require the categories to be defined before analysing the stories, which would be extremely difficult, given the open-ended nature of the creative writing task. Creativity tests like the TTCT do have predetermined categories, but they have the benefit of normative data collected over many years.

Flexibility was probably the most challenging construct to operationalise in this study. It could not be measured by the presence or absence of particular words, in the way that Fluency and Originality could. Instead, it needed to be defined by relationships between words or elements in the stories, and so a primary difficulty lay in being able to identify a genuine relationship with confidence. The definition used in this study (viz., non-semantic pairs in the same or adjacent clause) was selected because it would minimise the need for interpretation, and therefore minimise the risks of confirmatory bias. There was no need to judge if the elements represented by the words were sufficiently connected in the narrative;



[6] Bearing in mind the issues around operationalisations, Originality should perhaps be defined more broadly, to include unique adjectives and adverbs. Another way to broaden the content analysis would be to look at unique elements (nouns), unique descriptors (adjectives and adverbs), and unique actions (verbs) as separate outcome measures.

instead it was assumed that the words were connected if they were in close proximity. This definition was important, because the stories were first drafts written in limited time, so the narratives were not always clear. This definition also followed the established operationalisations used in previous research (e.g., Brophy, 2000; Torrance, 2008), by focusing on the shifts between ideas. For the sake of clarity, only shifts between unrelated words were counted, as it should reflect greater creative thinking to connect these kinds of words.

Admittedly, it is possible that this definition was too strict and may have missed some of the categorical shifts in the stories. Creative writing styles also vary, so some participants may have deliberately written their stories in a non-linear structure, with the consequence that some of the connected story elements were not written in consecutive sentences in the text. Underestimated Flexibility due to unconventional writing styles probably does not explain the pattern of results for Flexibility, however. Underestimation would more likely occur with the participants who wrote more creatively, either from the experimental manipulation or general ability, whereas participants who wrote in more conventional linear formats would receive a more accurate score. The statistically non-significant between-group difference for creative aptitude measures (TTCT and CAQ) suggest that the lower Flexibility scores in the SLEEP, WAKE, and REM groups were not due to a large portion of highly creative individuals in those groups who were not measured properly. The experimental manipulation could account for the results, but as has been noted with the Fluency data, the Flexibility between-group differences contradicted the experimental hypotheses and, furthermore, were statistically non-significant.



A combination of three factors seems to be the most likely explanation for the Flexibility results. Firstly, the confound with Fluency influenced the general trend. Secondly, Flexibility might be a less valid quantitative measure of divergent thinking, in comparison to Fluency and Originality. It is a relatively vague construct and there is no straightforward way to quantify the “distance” of a conceptual shift. Finally, high within-group variability may have concealed any differences that are attributable to the experimental manipulation. Issues around variability will be discussed further in the Limitations and Proposed Solutions section.

In summary, even though individual measures of divergent cognition did not yield the expected results, interesting trends can be observed when the relationships between outcome measures are taken into account. Although divergent cognition is often conceptualised into separate constructs of Fluency, Flexibility, and Originality, the current data show that it is important to remember that the constructs are measures of a single cognitive process; one therefore needs to interpret the results as a whole and not as a collection of disparate dependent variables.

**Quality of Incubation and Creative Aptitude**



Considering previous research showing that highly creative people have different sleeping patterns, as well as differences in dream structure and content, compared with the average (e.g., Domino, 1976; Healy & Runco, 2006), it was worth investigating the interaction effect between creative aptitude and the experimental conditions for creative task performance. Fisher's *r* to *z* transformation is an acceptable alternative to factorial ANOVA as a test for interaction effects. Although the findings should be interpreted cautiously, especially with respect to causal relationships between variables, some interesting patterns emerged that suggest possible avenues for future investigations in sleep and creativity.

Firstly, the significant comparisons suggest that ideal incubation conditions can be as important as general creative aptitude for predicting performance on creative tasks. An ideal incubation condition would be an environment that facilitates at least one form of incubation. Although Flexibility might be a problematic measure of divergent cognition, it does illustrate this effect. Participants in the SLEEP group had an interval of uninterrupted normal sleep, which should provide ideal conditions for autonomous incubation. Participants in the REM group, in contrast, had disrupted sleep with minimal REM-stage sleep. Theoretically, REM group participants should have had reduced opportunities for autonomous incubation, along with minimal opportunities for interactive incubation because they were asleep. At the same time, baseline creativity had no predictive value for task performance in the SLEEP group participants, whereas it had moderate predictive value for task performance in the REM group participants. This pattern of results suggests that factors other than baseline creativity were important in predicting task performance for participants in the SLEEP group. The nature of their interval is the most likely explanation, because, in comparison to the REM group, it is the only difference in their treatment during the experiment.

The statistically significant comparison between the WAKE and NO-INT group on the Originality outcome variable also reflects the incubation interaction effect found for Flexibility, but with a variation. Theoretically, one would expect participants in the WAKE group to have had more interactive incubation: they had the interval period of 6 hours within which they performed their usual daily activities and had many opportunities for stimulation from environmental sources and social interactions. They might have also engaged in autonomous incubation. In contrast, participants in the NO-INT group had minimal opportunities for incubation of any kind, with at most 15 minutes between memorising the list-words and writing the creative story. Again, baseline creativity had no predictive value for determining performance on the Originality outcome variable for participants in the WAKE group, but did appear to play a role in the NO-INT participants' performance. This important finding adds further support to the possibility that, under optimal incubation conditions, aptitude is less important for creative task performance than the experiences and cognitive processes that occur during incubation. Thus, although the ANCOVA results did not confirm the hypotheses, these results do give some support to the notion that sleep, as an ideal incubation condition, can facilitate creativity.

The complication arises with the correlation between baseline creativity and Originality under the NO-INT condition. In this group, the moderately negative correlation coefficient indicates that, to a small extent, more creative participants in this group actually used fewer unique words than the less creative participants. Baseline creativity was not helpful for performance of the NO-INT participants on the Originality measure. Bearing in mind that the Flexibility scores were based on list-word use, while the Originality scores are based on non-list word use, the result suggests that incubation is more important for elaboration. Another explanation is that participants in these groups were primed to use interactive incubation, because their participation occurred only during waking consciousness, with no encouragement or suggestions to use autonomous incubation or primary modes of cognition.

Both explanations imply that more creative people are more reliant on incubation, and particularly interactive incubation during waking consciousness, for elaboration in creativity.

Perhaps interactive incubation predominates over autonomous incubation during waking consciousness because the underlying cognitive processes for the latter are inhibited. Participants in the WAKE group's lower, although not statistically significantly so, performance on the Originality measure compared with participants in the SLEEP group would be understandable if those in the WAKE group did not have the benefit of both modes of creative processing. Whether or not interactive incubation is important for creative elaboration, the originality of more creative people appears to suffer when deprived of an opportunity to process task material in the background.

Another complicated pattern of results can be seen in the comparison of WAKE and NO-INT groups for Design Fluency-TTCT correlations. High baseline creativity moderately predicted poor performance in the WAKE group, while high baseline creativity weakly predicted high performance in the NO-INT group. Because the Design Fluency outcome measure assesses improvement from Trial 1 to Trial 2 of the task, it appears that, after a period of time where they could have engaged in incubation, more highly creative individuals in the NO-INT group tended to show an improvement, whereas more highly creative individuals in the WAKE group were more likely to show a smaller improvement.

One explanation for this pattern of data is that the WAKE group participants with high baseline creativity were more likely to "reset" their capability on this task during the interval. They might have forgotten the additional solutions they generated after the first trial, so that when they performed the second trial they approached it as if for the first time. In contrast, the NO-INT group's creative participants were primed for performance by the end of Trial 1 and still maintained readiness to perform at optimal levels at the beginning of Trial 2, after having completed a very different creative task in the verbal modality. This interpretation is consistent with previous research showing that ideational fluency can diminish within a brief period of time, but is enhanced when participants shift between different types of creative tasks in a similarly brief timespan (Howard-Jones & Murray, 2003). This shifting process is theorised to defocus attention and act as a form of incubation.

Consequently, participants in the NO-INT group may have had a period of incubation in the relatively brief period between Design Fluency trials. There may be appropriate lengths for incubation periods that depend on the length and complexity of the relevant task. In this case, it is possible that a brief incubation period is needed for optimal performance on the comparatively simple and short Design Fluency task, whereas optimal performance on the creative writing task, primed by the longer and more complex memorisation task, required a correspondingly longer incubation period.

Other factors to consider are that incubation may operate differently with visual tasks compared with verbal tasks and that the participants were not informed that they would perform a second trial for Design Fluency. This was necessary to prevent the WAKE group participants from consciously preparing for the second trial during the interval period. Consequently, there was no explicit motivation for incubation in Design Fluency and therefore incubation may not have played any role in this task.

In summary, the results of the Fisher *r* to *z* transformations analyses give some possible insights into the relationship between creativity and different states of consciousness: (a) quality of incubation could be as important as general aptitude for creative performance, (b) autonomous and interactive incubation may be distinctly different neurocognitive processes, and (c) incubation periods may be more useful when tailored to the characteristics of the relevant creative task. Some strategies for testing these findings systematically will be discussed in the Future Directions section.

**Content Analysis versus Independent Ratings**

As stated before, creativity is difficult to measure because it is difficult to define. Creativity is also commonly perceived as an intangible, intensely subjective quality. For reasons such as these, the controversy over measuring creativity is similar, if not greater, than the controversy surrounding measuring intelligence. Considering the vague, intangible nature of creativity, one might expect that impressionistic appraisals of a creative work might be more accurate than analytical, deconstructive measurements. The data obtained in this study challenge that expectation. The stories were scored blind for both the content analysis and independent ratings. The content analysis involved counting instances of specific words, while the independent judges gave general appraisals of the stories, based on broad constructs. The content analyses returned a significant result and a few clear, but statistically non-significant, trends that reflected the hypothesised between-group differences. In contrast, the independent ratings did not discriminate between the groups.

The low inter-rater reliability is the most likely cause for the statistically non-significant results based on ratings by the independent judges. Despite receiving standardised instructions and definitions for the constructs they needed to assess, the judges still had very different ideas about what constitutes “creativity” in the form of divergent and convergent attributes. The results confirm that creativity is normally perceived in very subjective, individual ways. The results also suggest that analytical approaches to measuring creativity may be more effective than non-analytic approaches in some situations.



The validity checks between the two approaches indicate that both were measuring the same underlying constructs, however. The statistically significant positive correlation between Originality (analytic measure) and Story Divergent (impressionistic measure) shows that the use of unusual words is a useful indicator of creativity in verbal tasks. The connection between Originality and Story Divergent is interesting, because the scores were derived in very different ways. A computer-based search was used to test the uniqueness of each noun, by checking for other instances of the word in all the other stories in the sample, to derive the Originality measure. When giving the Story Divergent measure, the independent judges were asked to score the stories in the order they received them, and probably did not read all the stories before giving ratings. Although the judges were probably not aware of the uniqueness of the non-list words in each story, this appears to have been an important factor in how they rated the stories. Therefore, the convergent validity of Originality with independent ratings of divergent properties of the stories shows that uniqueness of words in the sample is an accurate indicator of uniqueness of those words in general.

The discriminant validity of Originality with Story Convergent attributes, indicated by the significant negative correlation, shows that there is a genuine difference between these constructs. The negative correlations of Originality with Fluency and Flexibility are further evidence that Fluency and Flexibility operated as inverse constructs to Originality. The moderate inverse relationship between Story Convergent and Flexibility might be explained by participants who wrote stories with a high density of unrelated list-words in close proximity, which would lead to a high Flexibility score. In those cases, the stories may have appeared incoherent to the independent judges, who consequently awarded those stories low Story Convergent scores. The inverse case would have been where participants wrote more coherent, logical stories with mainly related list-words in close proximity, resulting in a low Flexibility score in the content analysis, but obtaining a high Story Convergent score from the independent judges. Thus, there was discriminant validity between the Flexibility and Story Convergent measures. By extension, the discriminant validity also confirms that divergent and convergent thinking are distinct and separate processes.



An unexpected finding with the validity analysis was the statistically significant moderate positive correlation between Story Convergent and Story Divergent. Although the independent judges were instructed to treat divergent and convergent qualities as separate constructs, and were allowed to give very different convergent and divergent scores, it appears that they were influenced by some common factor between the two constructs, in each case. This factor might have been the general “quality” of the story and the judges may have struggled to separate out the contributions of divergent and convergent thinking to the overall creativeness of each story. Thus, although there was discriminant validity between convergent and divergent measures when comparing the analytic and impressionistic measurement techniques, there was no discriminant validity between the two impressionistic measures of creative thinking. More work will be required to refine the independent ratings approach to measuring creativity that was used in this study

**Incubation and Memory Consolidation**

One of the theoretical underpinnings of this research was that memory consolidation and incubation may be similar processes. Memory consolidation is understood to be an automatic, ongoing process that involves restructuring encoded memories in a way that facilitates long-term retention (Zillmer, Spiers, & Culbertson, 2008). Previously discussed research (e.g., Plihal & Born, 1999) also indicates that memory consolidation occurs more effectively during sleep, perhaps because there is little distraction from new experiences that would are encountered during waking consciousness. Similarly, both autonomous and interactive incubation are theorised as at least partially background processes, where encoded material is restructured to result in creative solutions to "problems". Research (e.g., Cai et al., 2009) also shows that sleep can facilitate incubation. These common features between incubation and memory consolidation are suggestive of a common underlying neurocognitive process. To some extent, this research tested the idea that incubation will occur spontaneously, in the same way that memory consolidation does. The data obtained in this study, however, do not support this prediction.

Participants were not informed that they needed to memorise the word-list for a *creative* task and therefore were not explicitly motivated to incubate the words. Thus, any incubation that might have occurred during the interval periods would have been mostly spontaneous. One way to interpret the mainly non-significant results obtained in this study is that little or no spontaneous incubation occurred during the interval periods. Alternatively, incubation may have occurred inconsistently, with some participants engaging creatively with the task material in the interval, while others did not. Thus, although the participants effectively encoded and consolidated the list-words (the Recall results confirm this fact), generally they did not appear to process the list-words in any other way during the interval period, perhaps because they had no reason to do so.

Some previous research supports this interpretation. Studies like that of Cipolli et al. (2001) show that items that are perceived as important for a task are more likely to manifest in dreams during subsequent sleep. Anecdotal evidence also supports this view. The famous authors and scientists mentioned in the Introduction usually only had their breakthrough insights after working and struggling on their projects and problems for a period of time before the relevant night of sleep.

There are possible functional reasons for why incubation might not occur spontaneously or simultaneously with memory consolidation. The restructuring that can occur in incubation may be too extreme for the purposes of memory consolidation. Creative ideas are often strange because they involve associations between almost entirely unrelated concepts or elements. If these kinds of juxtapositions were included in consolidation, memory inaccuracies might occur with greater frequency. Perhaps this reason is why REM sleep, noted for dreams with bizarre content, has been associated with creative incubation, but not with episodic and semantic memory consolidation.

Another interpretation of the non-significant results is that incubation did occur spontaneously in the interval periods, but that the *quality* of incubation was similar across the different conditions. A major assumption of this research was that autonomous incubation would be more effective than interactive incubation. This assumption was based on previous research showing that sleep facilitates insight (Wagner et al., 2004) and the importance of primary states of cognition for incubation (e.g., Fink & Neubauer, 2006). Based on the findings of this study, it would appear that autonomous incubation is not necessarily better than interactive incubation. On the Originality, Flexibility, and Story Divergent measures, outcomes where incubation would be particularly useful, participants in the WAKE group did not perform statistically significantly differently from those in the SLEEP group. Again, there may be a functional reason for the similarity in performance. It appears that autonomous incubation requires a reduced level of externally-directed attention, such as in sleep or trance states. These states of consciousness are not always practical to maintain, because they leave the individual vulnerable to external threats, yet it is often these very adverse circumstances that require creative solutions to overcome. As a result, interactive incubation, where external stimuli drive the cognitive restructuring process, provides an effective alternative to autonomous incubation.

These two interpretations are not necessarily contradictory. Perhaps many of the participants did not engage in creative incubation, but for those who did engage in incubation, they did so with roughly equal effectiveness, whether they were asleep or awake in the interval phase. What is clear is that incubation is driven by need and cannot be simplistically equated with memory consolidation. To reliably promote incubation in future studies of creative task performance, some methodological changes are needed.

**Limitations and Proposed Solutions**

This section discusses the problems encountered in this study that may have compromised the results and could explain the lack of statistically significant findings. Practical solutions to these solutions are offered as a means of improving the quality of results in future variations of this research.

Participant location may have confounded the results in this study. The Design Fluency results show similar performances for participants in the WAKE and NO-INT groups and similar performances for those the SLEEP and REM groups. The experimental SLEEP and REM groups participated at the Vincent Pallotti Hospital sleep laboratory, while the control WAKE and NO-INT groups participated in the ACSENT Laboratory at the University of Cape Town's Department of Psychology, a venue that was familiar to many of the control-group participants. The on-campus location could have also made the ACSENT laboratory setting less discomforting or threatening for the students. In contrast, most of the experimental-group participants had never visited the hospital before. Not only do hospitals have negative associations for many people, but the experimental-group participants were required to spend the night there with unfamiliar people and with polysomnograph electrodes and wires attached to their bodies.

Although care was taken to respect the experimental-group participants' needs for privacy as far as possible, and although those participants were given time to habituate themselves to the electrodes before sleeping, some participants may have found these conditions uncomfortable. If the control-group participants were more at ease in the ACSENT

Laboratory, it might explain their superior performance on the Design Fluency tasks and could also explain their better-than-expected performance some of the other outcome measures (e.g., Originality).

Apart from the negative effect of location, there may have been a minor positive effect from location as well. Although this research was chiefly concerned with investigating autonomous incubation during an interval, in the form of sleep, interactive incubation in the task locations may have occurred as well. It may be that the ACSENT Laboratory was a more stimulating environment than the sleep laboratory, as there were more objects in the room and more activity in the vicinity of the control-group participants. This positive effect was probably limited though, because it is only apparent in one outcome measure: Design Fluency. This task was visual, which also, as suggested above, might indicate that incubation processes work differently depending on the modality of the creative task. Furthermore, some of the experimental-group participants also made reference to objects in the sleep laboratory in their memorisation sentences (e.g., such as 'These electrodes are giving me *helmet* hair.'). This tendency to refer to nearby objects suggests that many participants found the sleep laboratory environment stimulating enough to use it to aid their memorisation in the experimental task.

Using a single venue for all phases of the experiment would be the best way to control for environmental effects, but logistical problems prevented this ideal situation and would still need to be solved. If the experiment were to be conducted at the sleep laboratory, then all of the participants would have to have organised transport to the hospital, which is some distance from the university, and consequently recruiting participants would have been more difficult. A solution for making experimental-group participants more comfortable would be using portable sleep laboratory equipment and conducting the experiment at the participants' homes. This would be less disruption for the participants and promote more reliable sleeping patterns. Of course, one has balance the benefit of this approach with potential confounds from inconsistent experimental conditions. Another solution would be to make the sleep laboratory more comfortable and home-like, so that it appears less like a hospital or laboratory environment, but without being too stimulating. This may be a good compromise, but was not practical for this study, as the sleep laboratory is part of the hospital and is required for medical use as well. A sleep laboratory at the university may be a better long-term solution.

Another difference between the groups was the effect on the participants' schedules. Those in the control groups participated during normal academic hours at times that did not interfere with their daytime schedule. The experimental-group participants, however, may have had alterations to their mealtimes and sleep routine, as well as usual evening activities. These disruptions may have acted as minor stressors, thus impairing the performance of participants in those groups. Specific effects from time of day of task execution can be excluded as an explanation for the pattern of results, because the NO-INT participants were split into morning and afternoon sessions. Either the afternoon could be the optimal time for task performance, which could explain the fact that participants in the WAKE group performed better on measures like Design Fluency, or the morning could be the optimal time, as suggested by participants in the SLEEP group's performance on Originality. If either of these possibilities were correct, one would expect the NO-INT group's mean performance to consistently fall somewhere between the WAKE group on one end and the SLEEP and REM groups on the other. This was not the case.



A noticeable feature of the data obtained in this study was the very high within-group variability. In many cases, the standard deviation was a similar value to the mean. For example, the mean Originality score for the SLEEP group was 7.21 words, with a standard deviation of 7.06 words. On the same measure, the NO-INT group had a mean of 4.05 words and a standard deviation of 4.17 words. This means that some participants scored almost double the mean for their group, while others had a score close to zero, even though the experimental conditions were nominally different between those groups. In another example, the group standard deviations for Design Fluency were all larger than the mean scores, indicating that many of the participants' performance on this measure actually declined from Trial 1 to Trial 2. The NO-INT group had the highest mean and the largest standard deviation for Design Fluency, indicating that some of the lowest-scoring participants were in this group, along with some of the highest-scoring participants. In some cases, the high error variance may have masked the between-group differences that could be attributed to the experimental manipulation, such as for Originality, and may have distorted the between-group differences in other cases, such as for Design Fluency.

The within-group variability does not appear to relate directly to any of the covariate measures, as almost all of the covariate measures used in the study did not yield significant differences. It seems that other factors were influencing the participants' performance. Specifically, baseline creative aptitude and verbal intelligence were not the only potential confounding factors in this study. Participant mood, motivation, and personality (Brophy, 2001) may have influenced the results as well. Further research will be needed to determine what other factors could affect participants' creative performance, especially in relation to sleep. Additional measures such as personality scales would therefore need to be added to the experimental protocol, to add more potential covariate measures that could control for more of the extraneous variability in the groups.

Another possibility is that the measures were not accurate or sensitive enough to measure the applicable constructs. Although the Torrance Test of Creative Thinking is a well-established measure, its primary application is for measuring creative aptitude in school contexts (Torrance, 2008a). It may be that the creative skills required for the tasks in this study were different. General creative aptitude may also be a more unstable construct than previously supposed, vulnerable to environmental and personality factors like those already mentioned. It might be necessary to measure baseline creative aptitude several times and obtain a mean score that would be more accurate than a once-off assessment, as was conducted in this study.



A common reason for statistically non-significant results in research is insufficient power due to a sample size that is too small. Although small sample size may have contributed to the pattern of results in this research to some degree, it is unlikely that it is the main cause and a larger sample size might also be logistically unfeasible. Firstly, previous studies investigating sleep and/or creativity have obtained statistically significant results with similar (e.g., Brophy, 2001) or smaller sample sizes (e.g., Christensen & Schunn, 2005; Cipolli et al. 2001; Wagner et al., 2004). Secondly, there were some statistically significant results: the ANCOVA test for the verbal Fluency score and the ANOVA test for the visual Design

Fluency score. These results were not in the expected direction, however, and it is unlikely that the trends would reverse with a larger sample size.

Furthermore, the power coefficient for this study was .76, assuming an effect size of $r = .50$, which could be considered satisfactory. The actual effect sizes obtained for the significant results were considerably smaller. If those results are indicative of the potential effect sizes one could expect for the other statistical tests, should they be significant, then a considerably larger sample size would be needed ($n$ = 1424, with effect size of .11). Replicating this study with that sample size would require approximately 700 participants to spend a night in the sleep laboratory, which is clearly beyond the scope of a Master's project. A better approach would be to alter the experimental design.

A repeated-measures design has the potential to improve the quality of results for this research, by improving experimental power and controlling for individual differences that might have confounded the results. Each participant could undergo all of the experimental conditions, thus controlling for their own baseline characteristics. The challenge in using repeated-measures for this study, however, is that participants will have experience on the experimental tasks on subsequent trials, which undermines one of the purposes of this research to some extent: to investigate how incubation can operate spontaneously. Participants were only told that they had to memorise the word list for use in a task in the next session. Once participants know that they are going to have to use the words to write a story, there is nothing to stop them from consciously preparing a story for later use, especially under the waking condition. Additionally, creative performance would likely improve with practice.

There are some ways of addressing these challenges, however. Counterbalancing the order of experimental conditions across the groups would control for practice effects. Anecdotal evidence for sleep facilitating creativity suggests that people need to have a goal or problem to address before creative incubation will occur. Empirical research also indicates that items that are of cognitive concern are more likely to manifest in dreams (Cipolli et al., 2001).

Consequently, a more fruitful avenue of research could be to inform participants that they will be using the study material for a creative task.

The problem remains with the WAKE condition, where participants could consciously rehearse a story during the interval period and even write the story as practice. It might be interesting to compare this kind of performance with a more purely unconscious incubation under the SLEEP condition, although it is likely that the WAKE condition would still lead to better performance, as the participants would have the opportunity for both conscious and unconscious processing of the task material. Another solution would be to keep the participants in a controlled environment under the WAKE condition. This solution was not used in this study, because of logistical problems with monitoring participants for 6 hours. Controlled waking conditions were also judged to be too onerous and impractical for participants, who would be less likely to volunteer for the experiment with this procedure. Furthermore, participating in all four experimental conditions as they were implemented in this study would discourage almost all volunteers, unless perhaps significant compensation was offered.



Recent research (Cai et al., 2009), however, has successfully demonstrated incubation effects in sleep with much shorter interval periods of only a few hours. In that study, sleep-group participants had a 90-minute nap during the day instead of sleeping overnight, while the waking controls spent the 90-minute interval period in a room listening to music. A waking condition like this would be feasible for this study. Performing the experiment during the day for all the groups would also remove the confound introduced by variable disruptions to the participants' daily routine. Experimental conditions with briefer interval periods and tested with repeated measures should be implemented in future research.

As previously discussed, most creativity research has focused on problem-solving and sleep, rather than on creative task performance and sleep. Although a need for more research in sleep and creative task performance was identified and some advantages for this approach were outlined, this research has demonstrated some challenges in measuring creative task performance that need to be overcome.

Firstly, it can be difficult to implement operationalisations of divergent thinking on creative work. For instance, there is some uncertainty as to whether the Fluency and Flexibility scores were valid measures of divergent thinking in this study. It is easier to quantify performance on problem-solving tasks than on production of creative work. Fluency is easily measured as frequency of solutions given, Flexibility as the range of solutions given, and Originality as the uniqueness of particular solutions.

Secondly, measuring creative performance may require more complex tasks requiring multifaceted cognitive skills, in contrast to the often simple scenarios and formats of most problem-solving tasks. The greater number of factors that could influence performance on the creative task could be another reason for the high within-group variability. The comparatively simpler problem-solving tasks produce "cleaner" data, which improves the chances of finding significant between-group differences. For example, Cai et al. (2009), the published study most similar to this experiment, did find significant between-group differences between waking consciousness, REM, and non-REM sleep intervals, for performance on a problem-solving task.



Rather than discarding creative performance tasks as impractical, the tasks should be simplified to produce clearer results. Simpler tasks would also be more useful for a repeated-measures design. A variation on the Alternate Uses Test (e.g., Fink & Neubauer, 2006) might be appropriate. Participants would be exposed to the relevant item before the interval phase and later asked to give as many uses as possible, after the interval. To make the task test verbal creativity more specifically, semantically unrelated word pairs could be given instead of items in the exposure phase. The participants will then generate as many possible connections between the words in the performance phase. This format would resemble a creative performance rather than a problem-solution scenario. The task is relatively simple and participants are unlikely to find it too onerous or challenging. The word-pairs can also be assigned in a counterbalanced fashion to different experimental conditions to control for confounding variables. The visual creativity component of the study should also be altered to make it more equivalent to the verbal creativity component. Participants could be given simple shapes or designs at the exposure phase and then draw elaborations or combinations of the shapes at the performance phase.

In summary, this study had some methodological limitations that may have impacted on the results obtained. These problems include variations in study location, discomfort from sleep laboratory equipment, insufficient statistical power as a consequence of the study design, insufficiently sensitive measurement tools, and high within-group variability. These issues can be overcome by using a single location for all testing, giving participants adequate time to habituate themselves to the experimental environment, simplifying and altering the experimental tasks, and using a repeated-measures design. Despite these limitations, some interesting findings were obtained that can be developed further in future research.



**Future Directions**

Although the Fisher *r* to *z* transformations gave some significant results that implied there is an interaction between creative aptitude and creative performance following different kinds of intervals, the interaction should be studied more rigorously. A 2 x 4 factorial design that combines creative aptitude (high vs. average) with level of consciousness during interval (asleep, awake, asleep with REM deprivation, and no interval) would be a useful approach. Instead of testing creative aptitude post-intervention, baseline testing should be conducted first and then the results used to assign participants to groups. Scores from the TTCT could be combined with the CAQ and possibly another creative test to ensure that each participant's creative aptitude is represented as accurately as possible. Participants scoring above the 50$^{th}$ percentile could be assigned to the high creativity group, while participants scoring below the 50$^{th}$ percentile could be assigned to the low, or average, group. Once participants are differentiated on creative aptitude, they could be randomly assigned to the four experimental conditions, but a better approach would be to expose the participants to all the conditions, following the repeated-measures design proposed above.

Depending on availability of participants, more extreme scores could be used for inclusion criteria, such above the 84$^{th}$ percentile for high creativity and below the 50$^{th}$ percentile for low, or average, creativity. Extreme differences between the groups would also increase the likelihood of detecting differences in creative performance based on creative aptitude. If the same university population were used for the factorial design, it might be difficult to obtain participants with very low scores, such as below the $16^{th}$ percentile. Although creative aptitude is only moderately or weakly correlated with conventional intelligence (Sternberg, 1999), most university students are presumably of average or above-average intelligence and therefore most would likely score within the average range on the TTCT; the data gathered during this study supports this assumption. Low-creativity participants could be recruited from outside the university community, but they may be below-average on tests of conventional intelligence, which could confound their performance in the study. Therefore, using participants who score below the $50^{th}$ percentile on the TTCT for the average-creativity group would be the more feasible approach.

Neuroimaging technology has become increasingly powerful and more accessible for psychological research. An interesting approach to studying the role of sleep in creative task performance would be to combine an experimental design similar to that used in this research with an imaging component. As previously discussed, there is research that has examined neural activity during creative thinking and other research that has investigated neural activity during sleep, but there is little or no research that has investigated the two processes together.

Although this study used EEG as part of a polysomnograph to record cortical activity in selected areas, it was for the purposes of identifying sleep stages and not for studying neural behaviour. Furthermore, EEG can only give a crude representation of neural activity and, in its non-invasive form, cannot detect activity occurring in deeper brain structures. This limitation is significant for this research, considering that the hippocampus has been implicated in both creative problem-solving and memory consolidation during sleep. Alternate imaging techniques would be functional magnetic imaging (fMRI) or positron emission tomography (PET). These imaging techniques would have the advantage of giving a record of activity in the entire brain and, particularly for fMRI, offer much higher spatial resolution than EEG.

This study's procedure would have to be modified, however, to make neuroimaging feasible for studying sleep and creativity. It would be difficult to conduct fMRI without using briefer interval periods, especially under the WAKE condition. Again, implementing Cai et al.'s (2009) protocol with brief daytime naps and controlled waking conditions would be a solution. Providing sleeping participants with earplugs would help them to fall asleep, but extra measures would need to be taken to minimise movements while they sleep. A PET scan, which is mostly silent, could be used instead during the interval period, but it would still be necessary to restrict the movement of sleeping participants.

It would be worth investigating neural activity during the interval period to gain a better understanding of the incubation process and how it might relate to other neurocognitive processes, such as memory consolidation. Some of the results from the Fisher's *r* to z transformations suggest that autonomous and interactive incubation may have different neurological bases; fMRI or PET imaging would be an effective way to test this hypothesis. Participants given material to incubate before the scanning period could be compared to a control condition, where participants are given no material to incubate. Both sleeping and waking consciousness should be investigated with a protocol such as this. Differences between verbal and visual creativity in the incubation phase that manifest in different patterns of neural activity could also be investigated.



Alternatively, imaging during the interval period could be omitted in favour of comparing neural activity between conditions in the post-interval phase, controlled by baseline activity in the pre-interval phase. This protocol would reveal brain-behaviour differences during creative performance that would result from differences in the interval phase. Bearing in mind previous research in sleep and in creativity, there are several brain regions of interest where one might find altered activity. For instance, one could look for reduced frontal activity coupled with increased occipital activity in the planning stages of the creative task, where one would expect divergent processing to predominate. Perhaps having an interval of sleep prior to the creative task would promote this pattern of activity more than an interval of waking consciousness, another hypothesis that could be tested with neuroimaging. Differences in hippocampal activity during task performance, which might represent different ways in which encoded and incubated material is retrieved and used, could also be detected in this kind of research.

In summary, future studies should compare highly creative participants with average participants and test each participant under different experimental conditions. This kind of design could test the additional hypotheses that more creative people are more likely to use incubation to enhance their work, and that drawing inspiration from dreams is a skill that requires practice. This kind of design can be combined with neuroimaging protocols, so that the brain basis for differences in creative performance can also be better understood. Simpler and conceptually purer creative tasks should also be developed, to increase the likelihood of obtaining clearer results.

## Conclusions

The aim of the study was to investigate the role of sleep in creativity. It was inspired by anecdotes and reports of people, some famous and others not so well-known, who gained creative inspiration from their sleep and dreams. Unlike most research in this area, I used a naturalistic task for assessing creative performance. The participants had to write a short story, as well as draw abstract designs. The purpose was to investigate creativity according to a generally accepted definition. The difficulties in defining and measuring creativity warranted using an array of outcome measures, based on the idea that even if some measures were not valid, others would probably work.



Despite using these multiple approaches, the hypothesis that sleep facilitates creative task performance was not confirmed. The basic results did not show a causal relationship between sleep and creativity. A deeper investigation and interpretation of the data did suggest that there was a connection between states of consciousness in the interval periods and performance on the creative tasks, however. It is also possible that the role of sleep in creativity is a small, occasional, and inconsistent effect. People may report receiving inspiration from dreams because it is an unusual and uncommon occurrence. Other factors could be more important for creativity and these may have affected the outcome of this study.

This research did have some flaws and limitations in its design and scope. The limitations may have also had an effect on the results obtained. Many of the confounding factors and potential obstacles were taken into account, however, so the findings do have some validity and do provide some useful, albeit tentative, insights. Furthermore, the limitations are not intractable. Most can be overcome with a few alterations to the experimental design in future studies. Although the study did not provide as many answers as hoped for, it has generated some interesting questions and ideas that can be successfully tested in future investigations.

The role of sleep in creative task performance should be studied further. Creativity is an important form of higher-order cognition and is a uniquely human trait. We use it not only when we paint pictures and compose music, but also to unravel scientific mysteries and to solve the everyday problems that challenge us. Understanding the relationship between sleep and creativity not only satisfies scientific curiosity, it also has important mental health implications. If the relationship is real, and some evidence suggests it is, then it underscores the importance of a good night's sleep for us to function at our best, in any endeavour.

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Appendix A

Probability plots for covariates and dependent variables for testing assumptions of normality

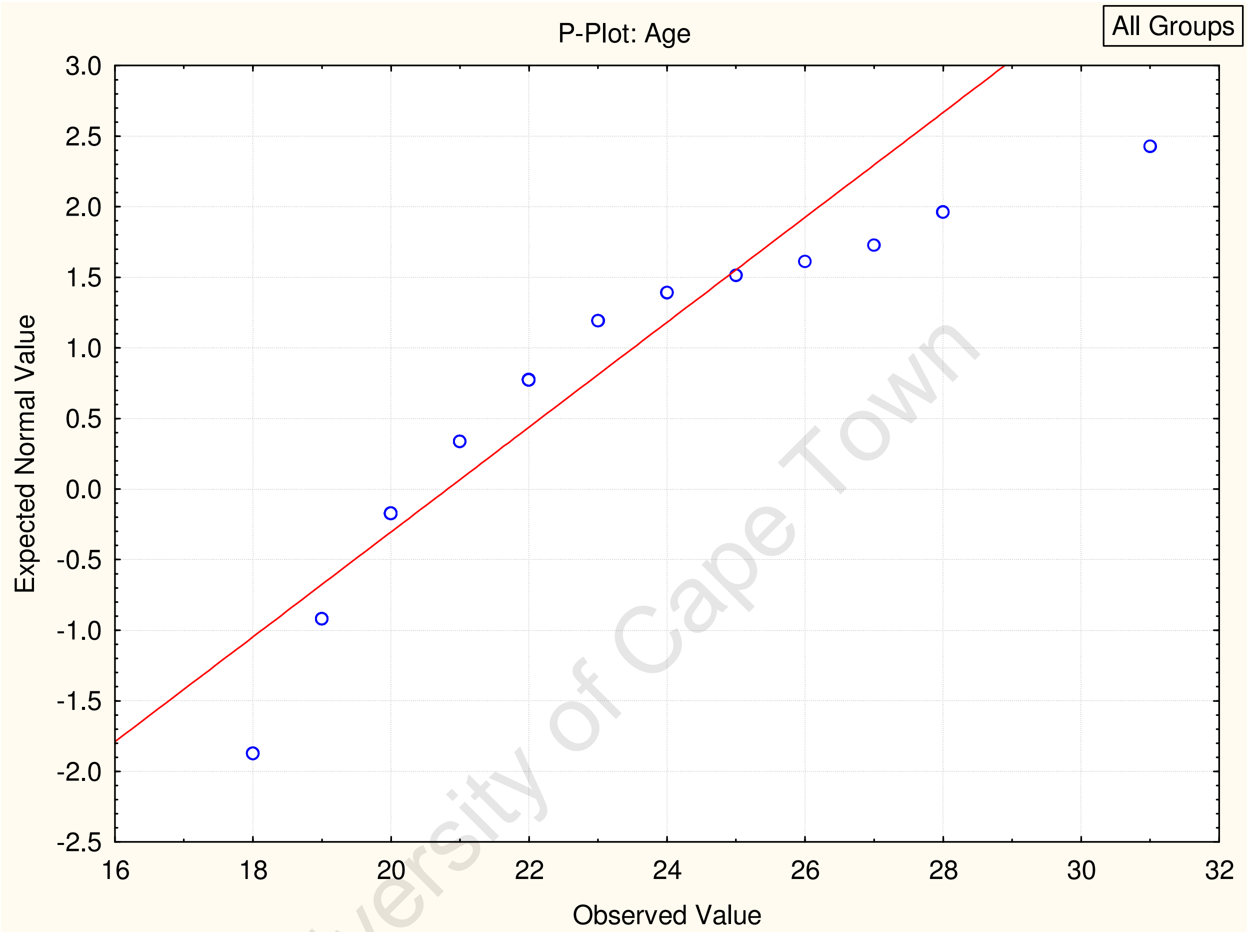



*Figure 1.* Age

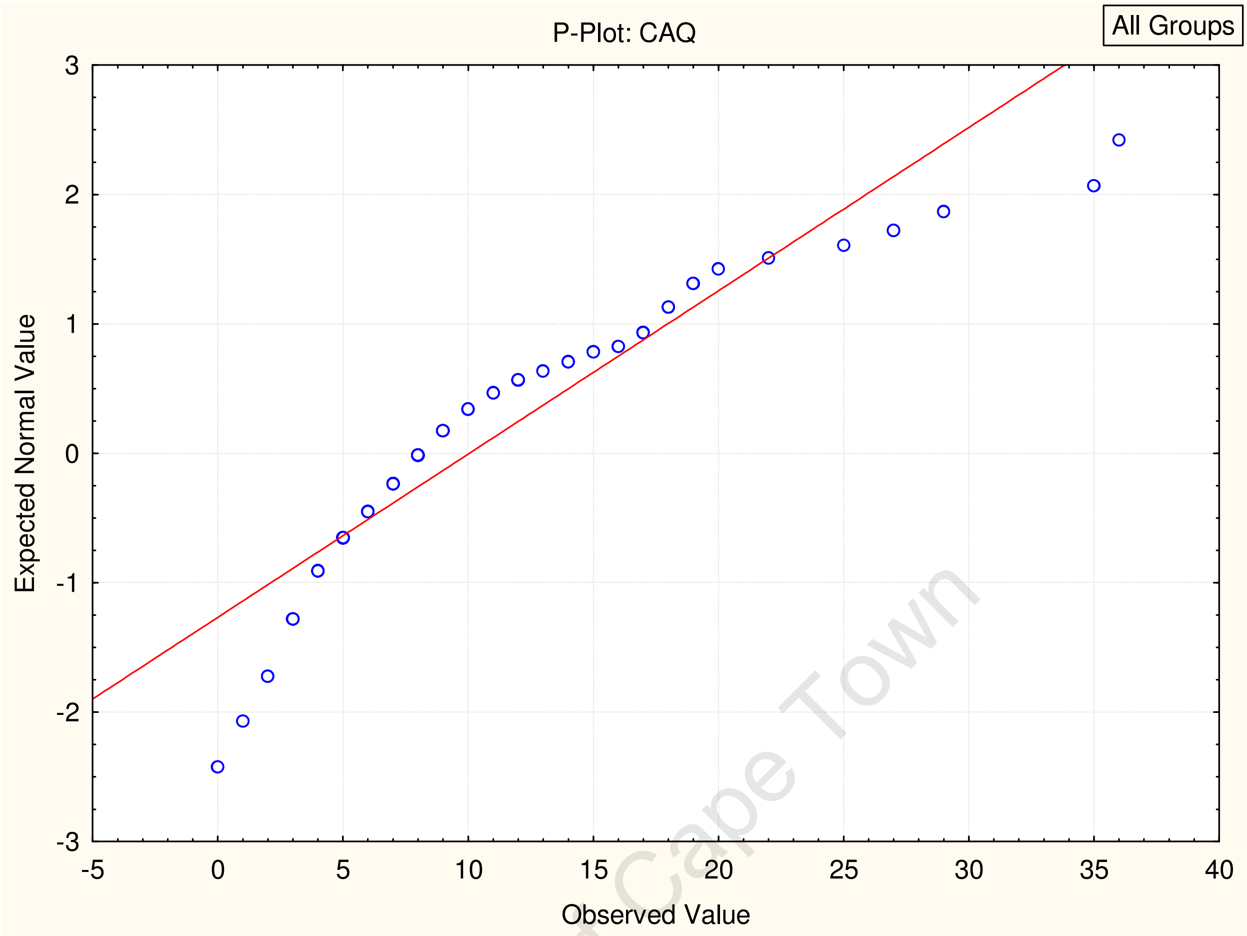



*Figure 2.* Creative Achievement Questionnaire

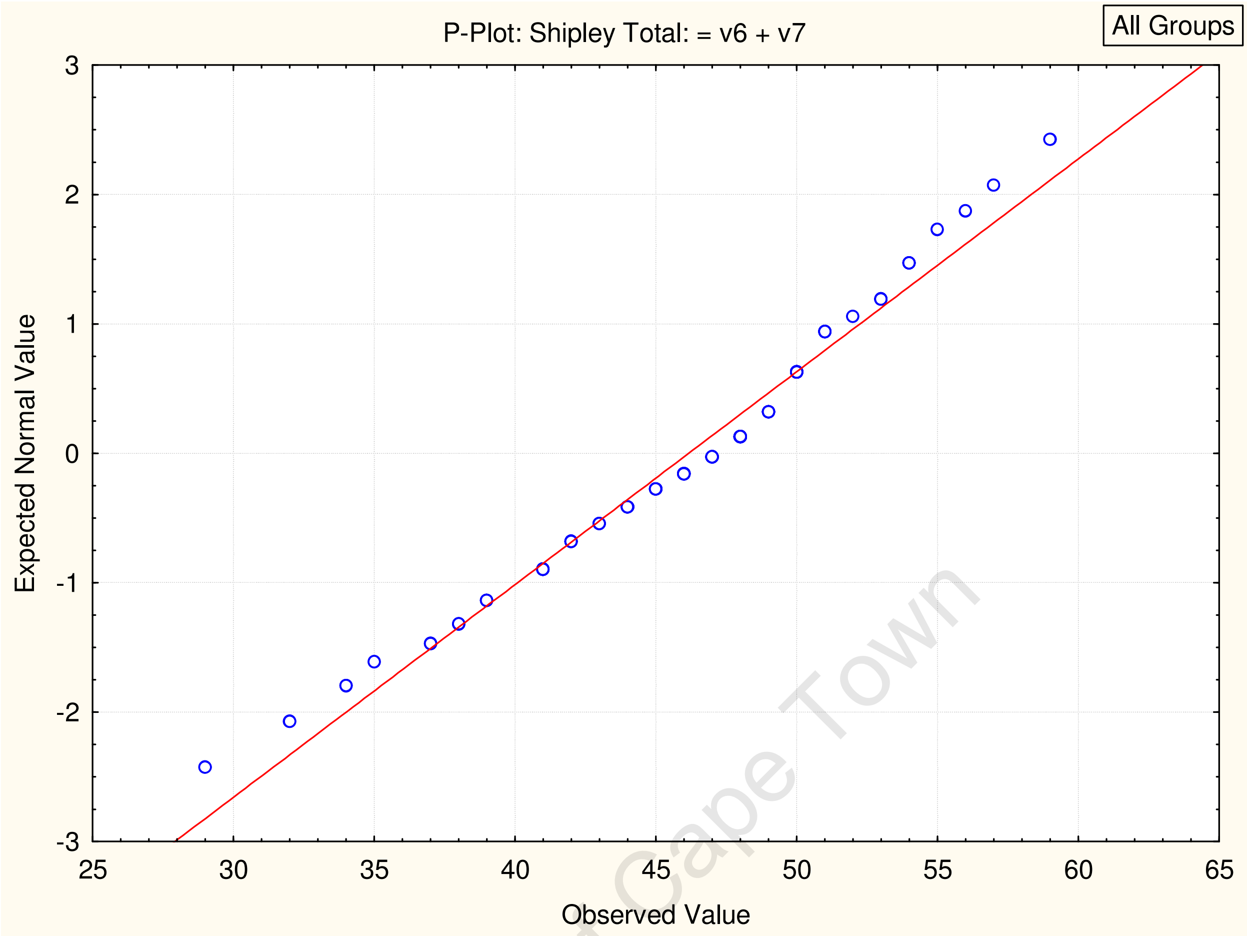



*Figure 3.* Shipley Institute of Living Scale

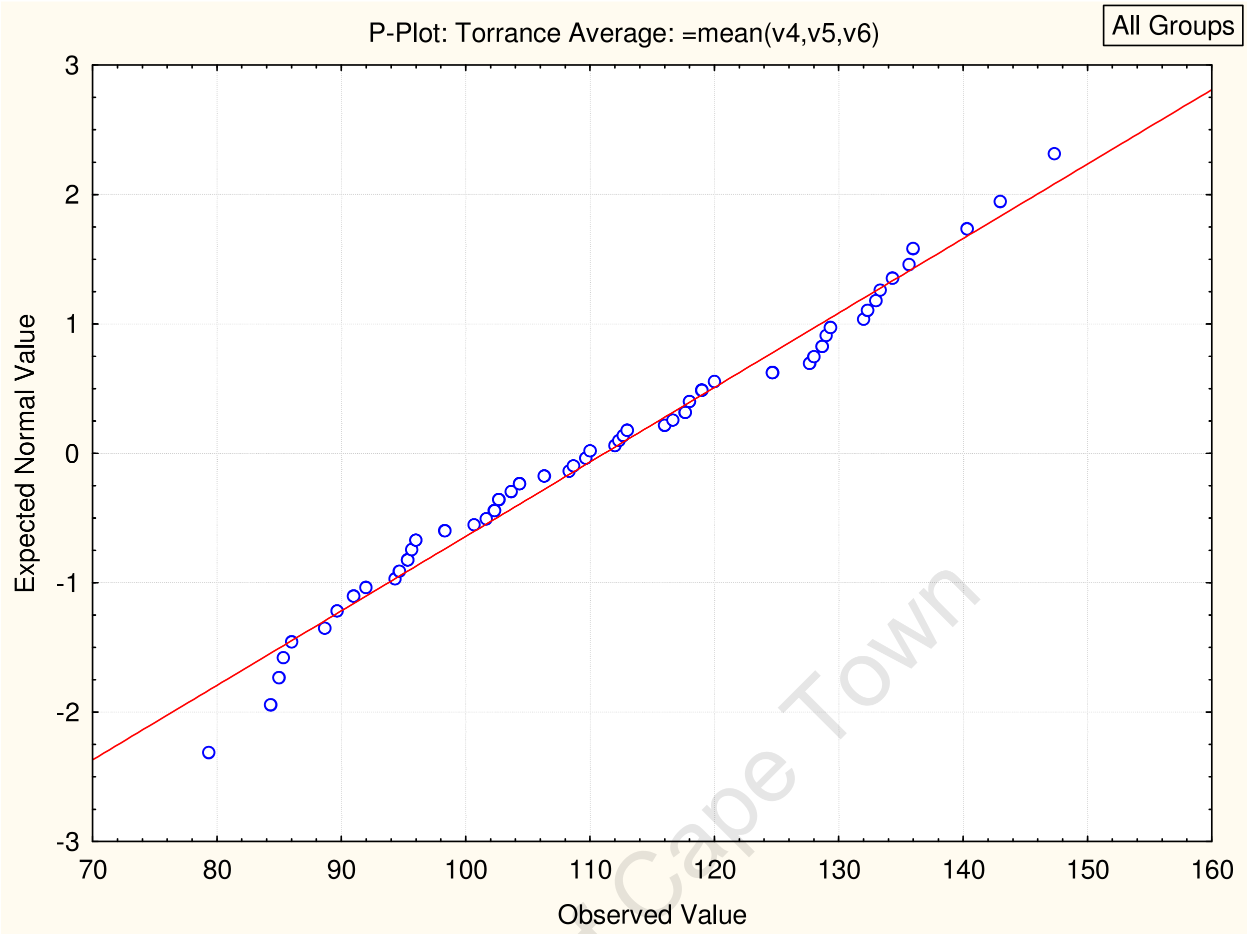



*Figure 4.* Torrance Test of Creative Thinking –verbal edition

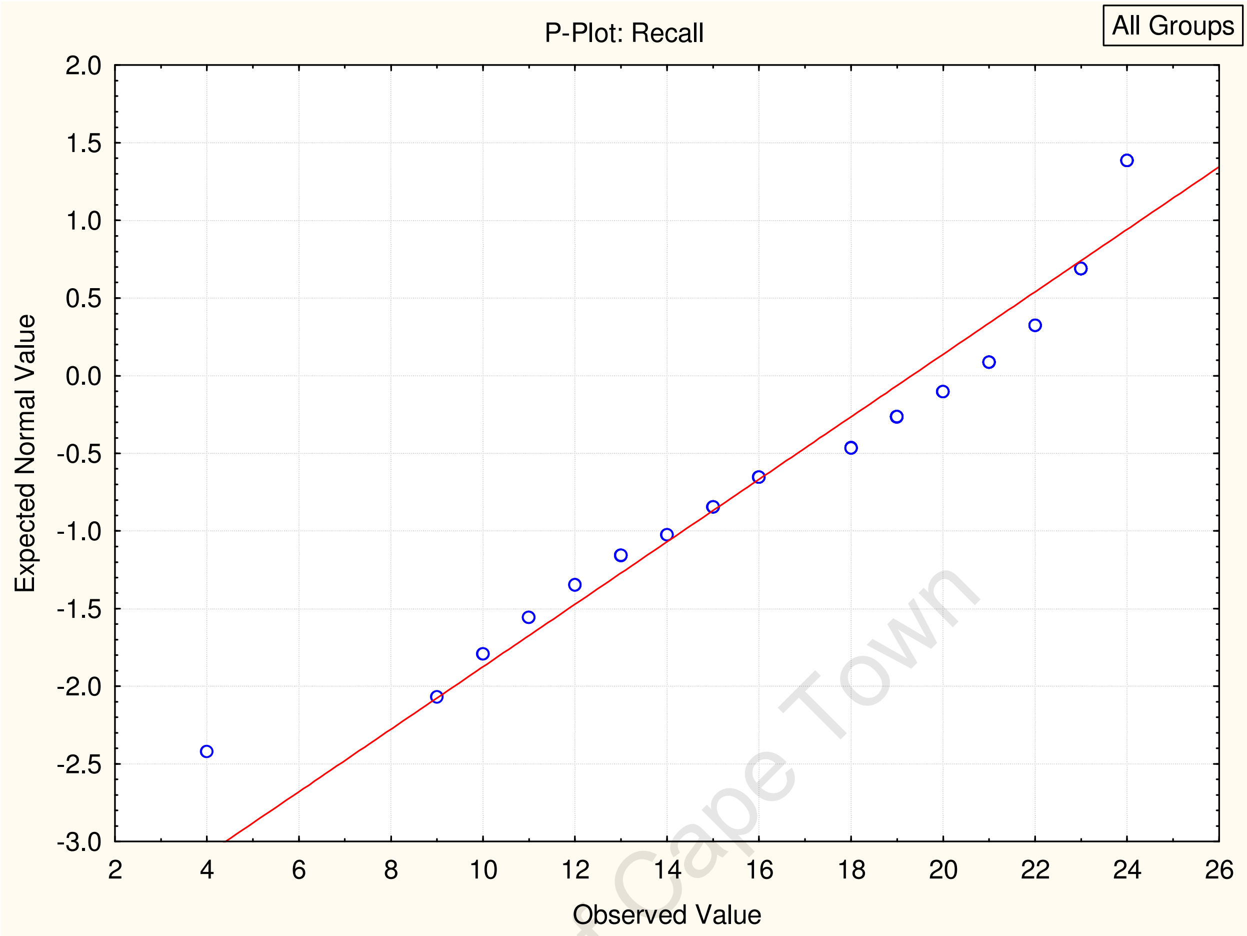



*Figure 5.* Wordlist Recall

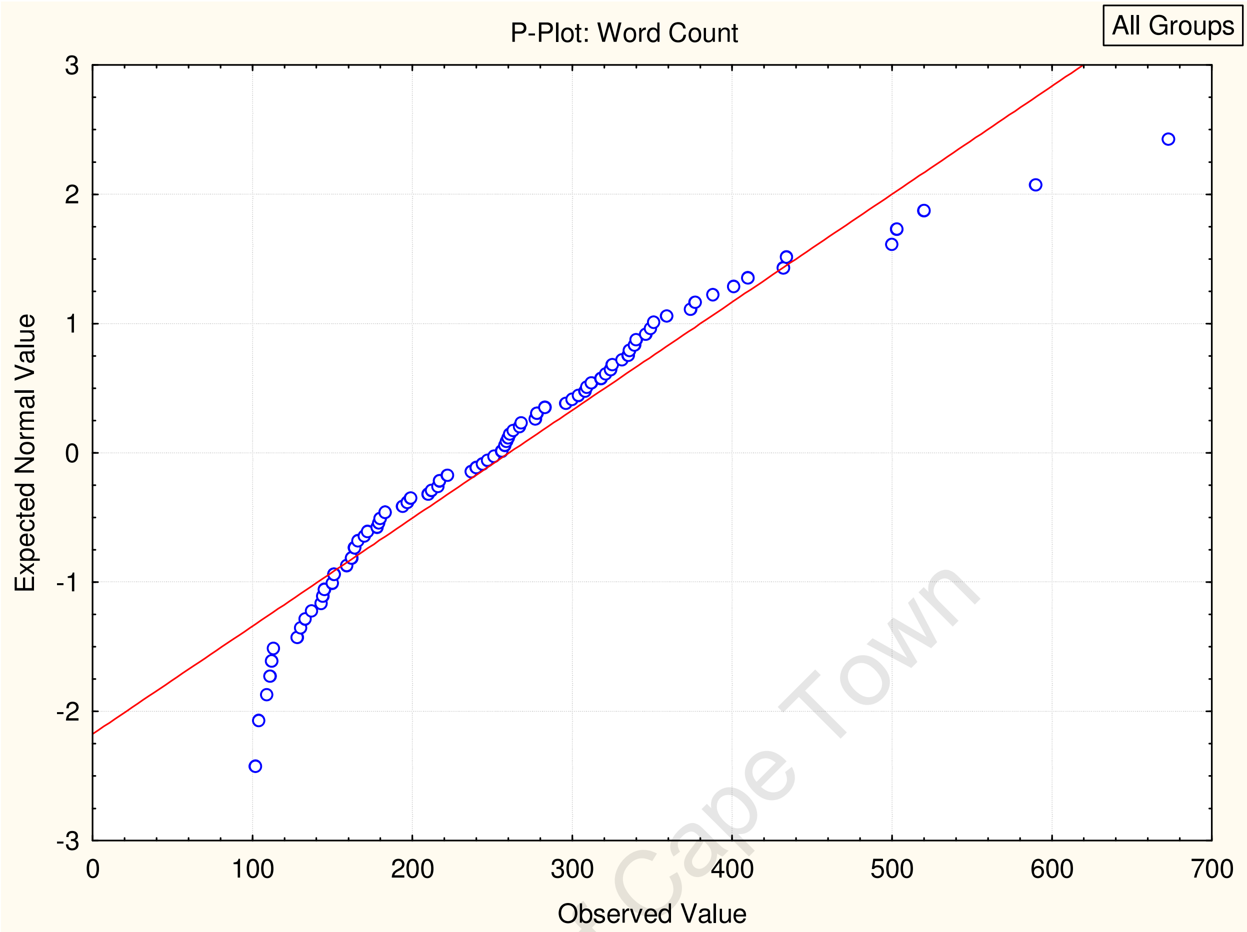



*Figure 6.* Word Count

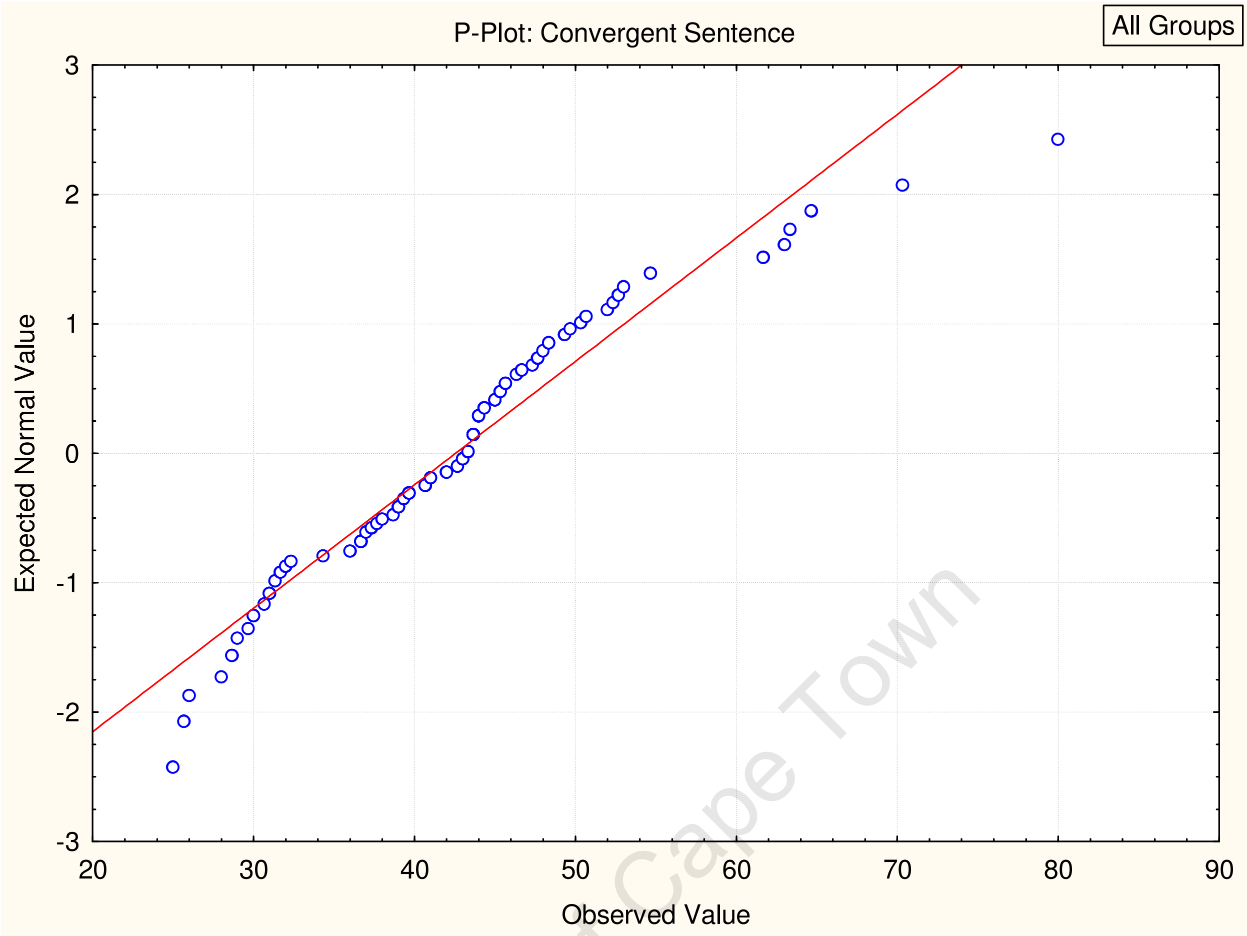



*Figure 7.* Sentence Convergent

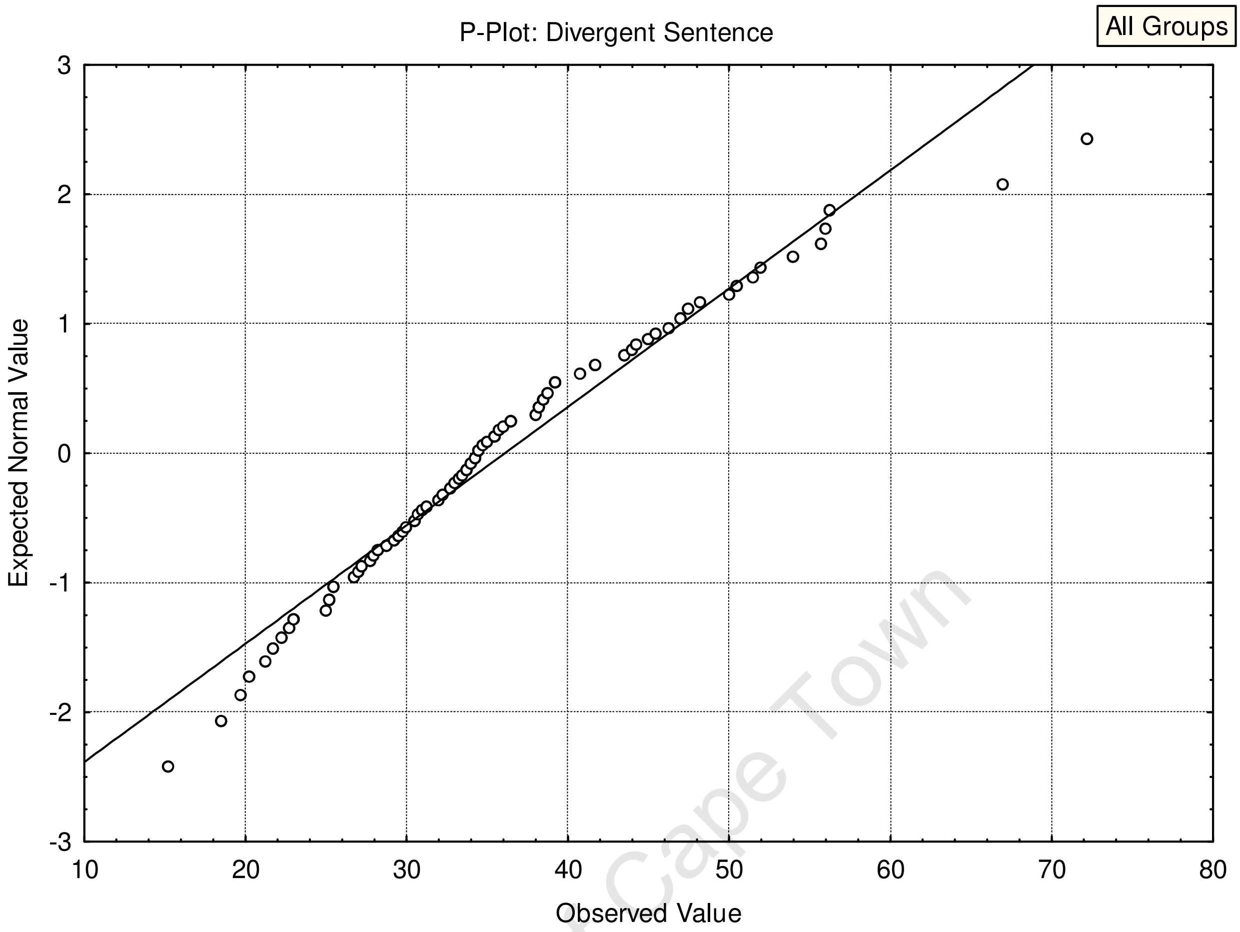



*Figure 8*. Sentence divergent

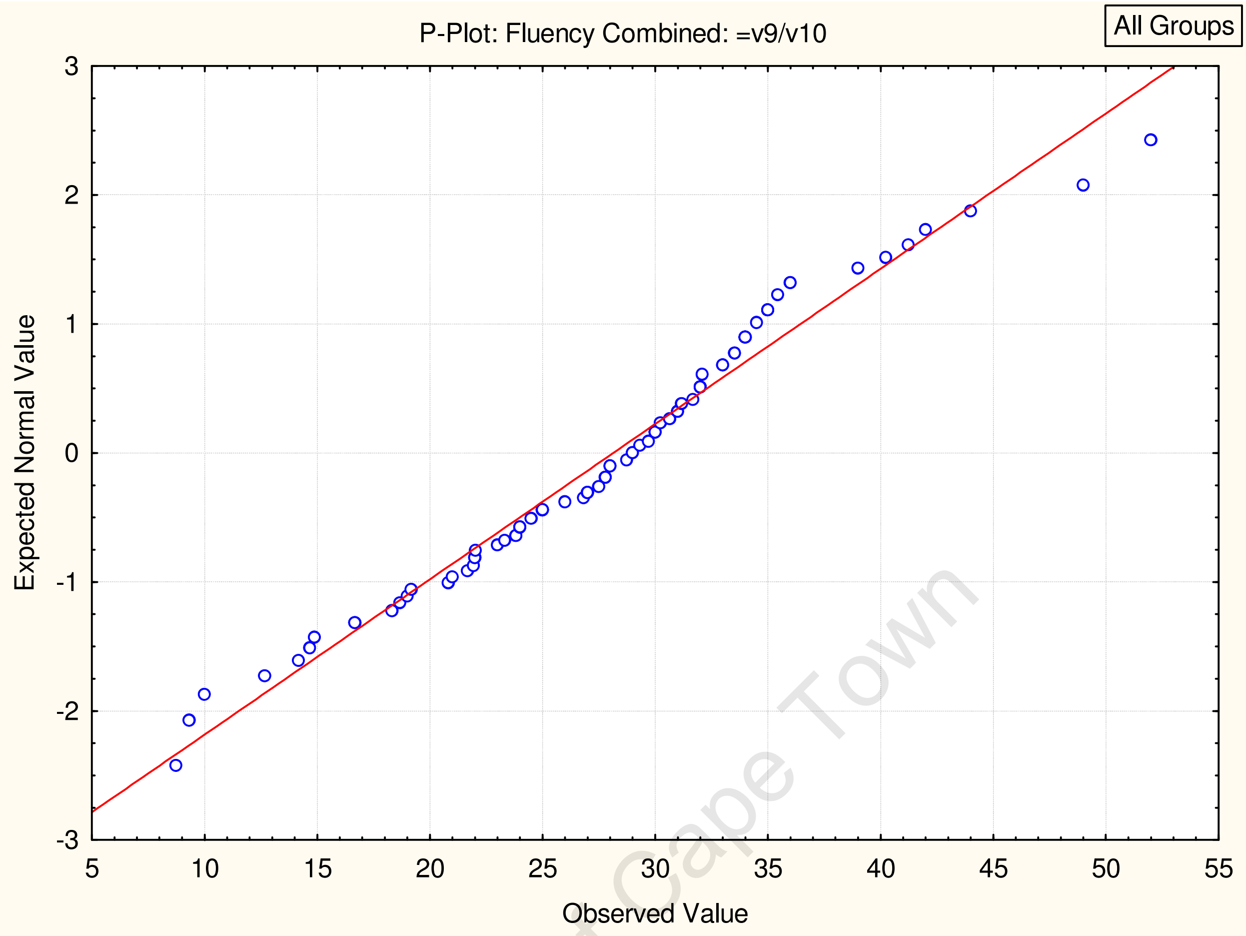



*Figure 9.* Fluency

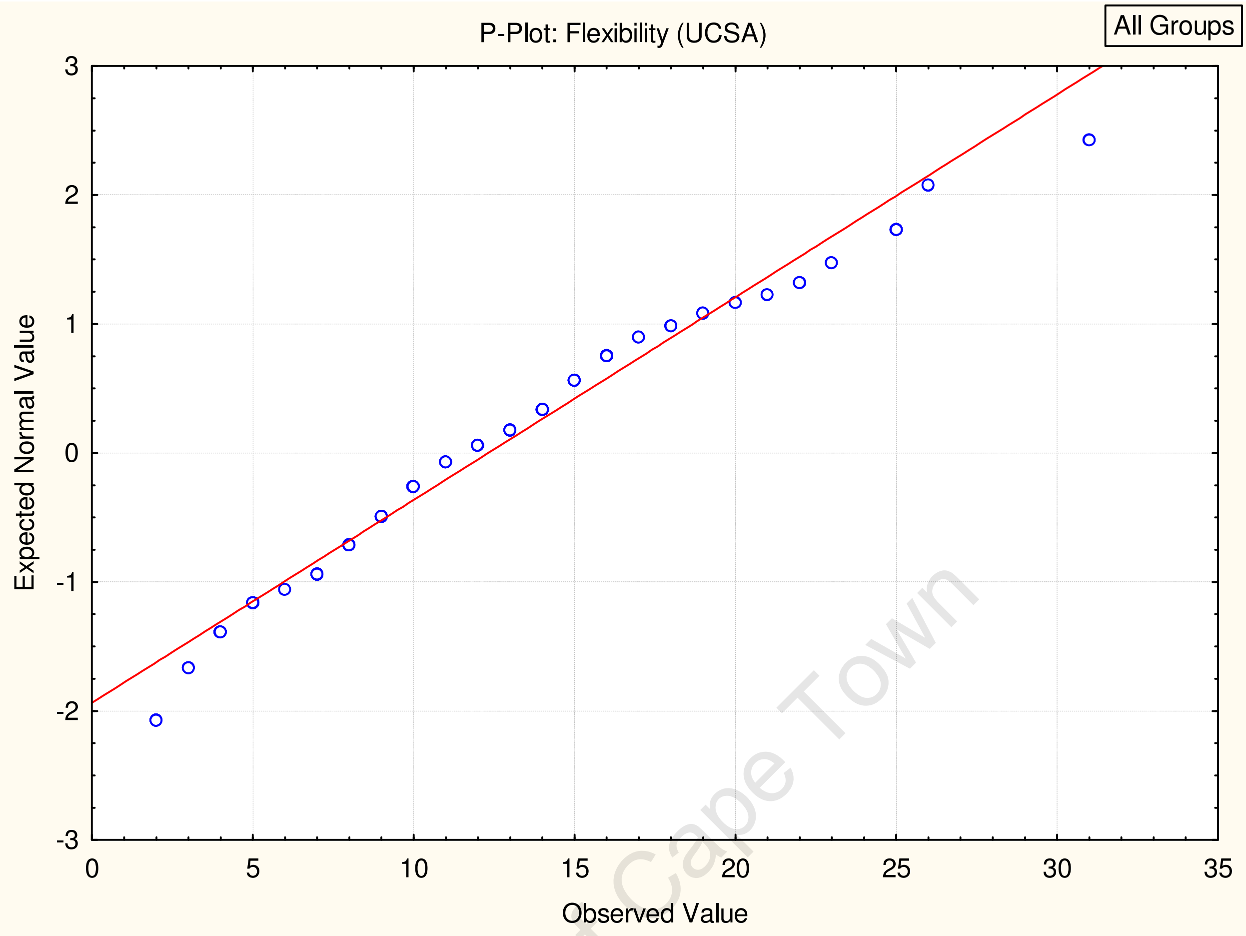



*Figure 10.* Flexibility

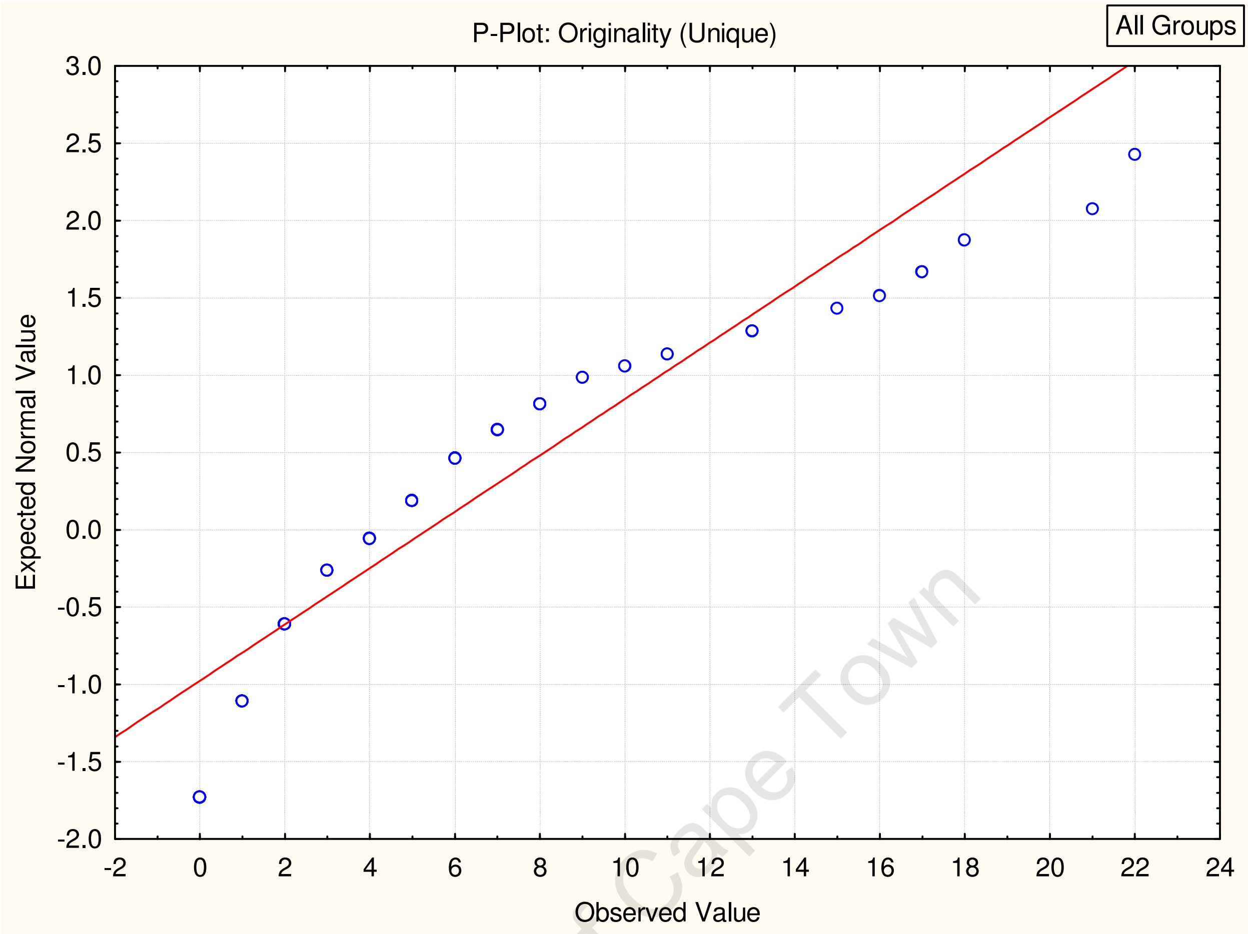



*Figure 11.* Originality


*Figure 12.* Story Divergent

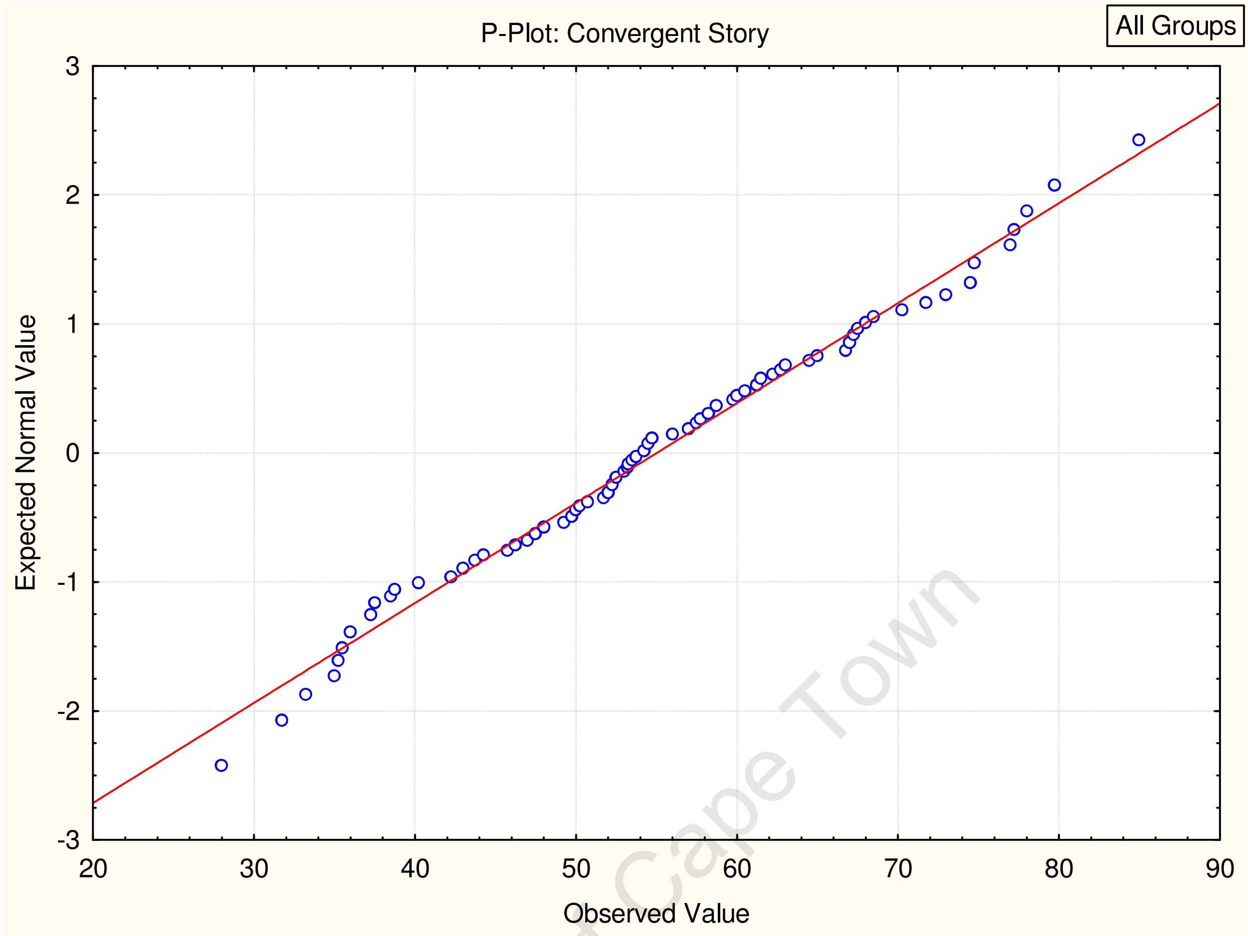



*Figure 13.* Story Convergent

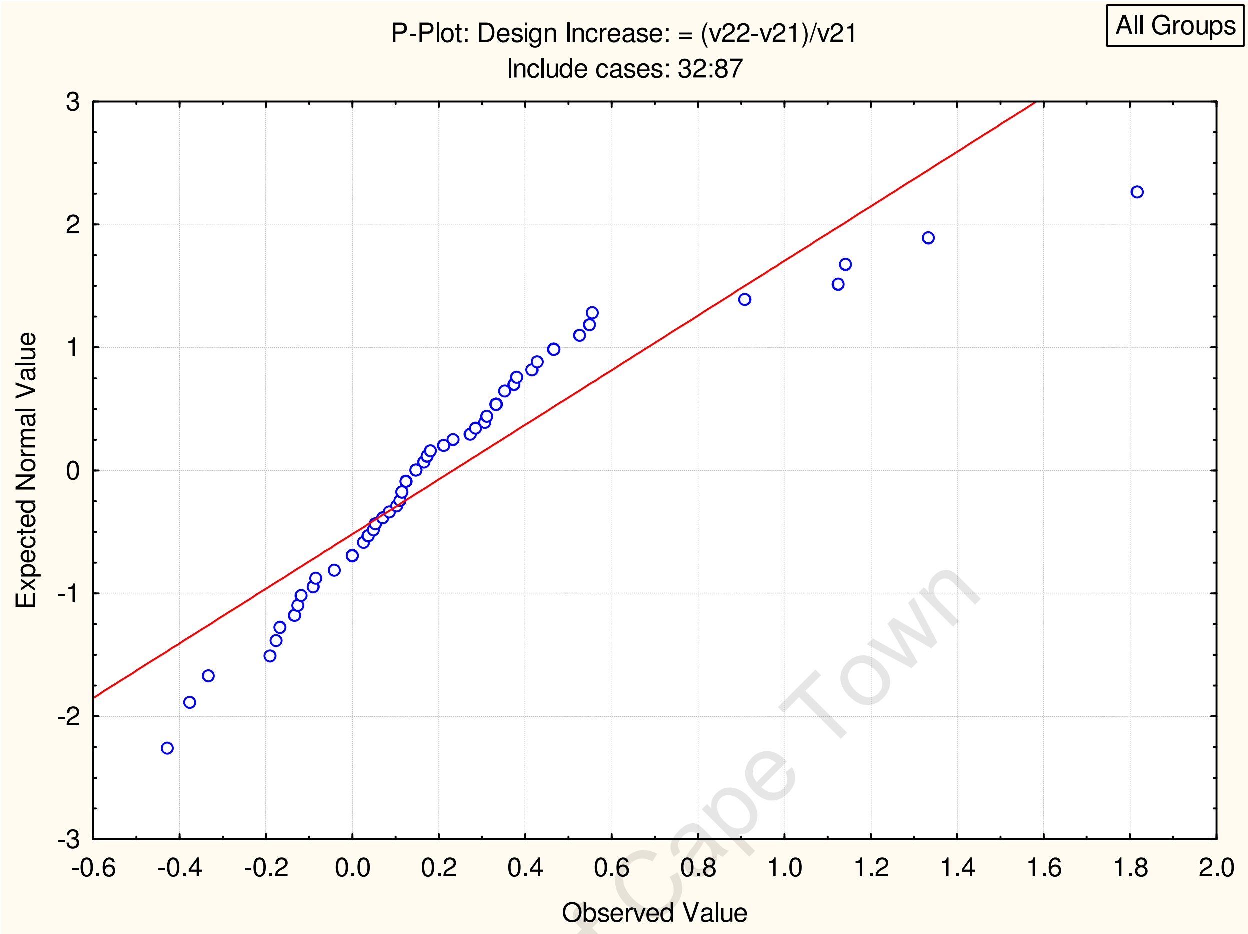



*Figure 14.* Design Increase

Appendix B

**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.

# Appendix C

## 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. 1 2 3 2 1 2 3 4 3 2 3 4 5 4 3 4 5 6 __ __
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:** _____ | | |

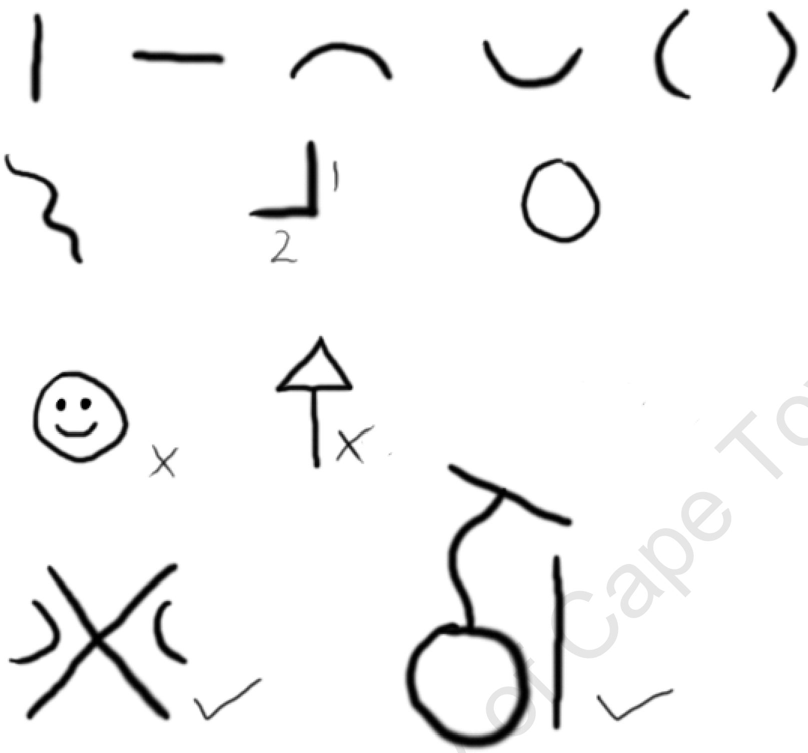
Appendix D

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 E

## Instructions for Design Fluency task





"For this task, I want you to draw as many different abstract, 4-line designs as you can think of in 4 minutes. For the purposes of this task, a line can be either straight like these, or curved like these [Point to lines on the first row]. The lines can also be squiggly, but if there is a sharp angle in the line, it counts as more than one line, like this: one and two [Point and count out numbered lines on the second row]. A circle counts as one line. Now, as the designs have to be abstract, they can't resemble recognizable symbols, or objects from the real world, so a smiley face or an arrow would not be acceptable [Indicate designs on third row]. Here are two examples of designs that you could do [Count out lines for each acceptable design on fourth row]. Remember: each design must consist of 4 lines, no more, no less."

Appendix F

***Informed Consent to Participate in Research and Authorization for Collection, Use, and Disclosure of Sleep Architecture Patterns, Dream Reports, Cognitive Performance and Other Personal Data***

You are being asked to take part in a research study. This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your sleep architecture patterns, dream reports and cognitive performance data, as well as other information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. By participating in this study you will not be penalized or lose any benefits to which you would otherwise be entitled.

- **Name of Participant ("Study Subject")**

____________________________________________________________

- **Title of Research Study**

"SLEEP AND VERBAL PERFORMANCE"

- **Principal Investigator and Telephone Number(s)**

Anthony Hodge

Department of Psychology

University of Cape Town

Contact number: 0732721876

Email: Ant.hodge@gmail.com

- **Source of Funding or Other Material Support**

URC Emerging Researcher grant

- **What is the purpose of this research study?**

This research aims to investigate the relationship between sleep and verbal ability, specifically writing ability.

- **What will be done if you take part in this research study?**

In this experiment, you will be called in for a sleep study for 1 night.

Before commencing the actual study, you will undergo a screening process whereby the Principal Investigator listed in # 3 of this form will take a full medical history from you. You will also undergo a physical exam by a medical practitioner attached to the project. This procedure is crucial so as to ensure that you do not suffer from any medical condition that may be worsened by your participation in the study or alternatively that may interfere with the results.

The sleep study will be arranged at a time convenient to you. You will retain your routine bedtime and waking time but will be asked to avoid caffeine and sugar in your diet for a few hours before bedtime. You will be required to come to the sleep laboratory based at Vincent Pallotti Hospital at about 8 p.m. and will be briefed once more, in detail, on the procedure.

To begin with, you will be required to perform a few written tasks that should not take longer than an hour altogether. After this relatively short set of exercises, you will be taken to a bedroom where you will be able to sleep.

While you are asleep, you will be wired to a polysomnograph (PSG) which is an EEG machine designed to monitor your sleep pattern. Electrodes will be placed on your head, under your chin and on your temples; these are completely safe and present no danger whatsoever to your health. They are designed to transmit physiological indications of the stage of sleep you are experiencing at a given point in time, to a computer monitor. Two researchers will be observing the monitor in an adjoining room, separated from your room by a large glass pane. One of them will be available to you for assistance at any time. The researchers may wake you several times during the night for the purposes of this study. You will be woken up by the researcher if you do not wake up spontaneously by 8 a.m.

Lastly, after breakfast, you will be required to do two more tasks that will last approximately 30 minutes.

You will be informed in detail about the design of the study and the research question we hope to answer with this study after you have completed the required task. You will also have the opportunity to ask questions and thus learn more about psychological research.

If you have any questions now or at any time during the study, you may contact the Principal Investigator listed in #3 of this form.

- **If you choose to participate in this study, how long will you be expected to participate in the research?**

Screening session: approximately 30 minutes. IQ test, creativity questionnaire & memory tasks: 2 hours. Sleep study: 1 night.

- **How many people are expected to participate in the research?**

30

- **What are the possible discomforts and risks?**

Sleeping in an environment other than your own bedroom might feel strange and uncomfortable at first. Great precautions will be taken to ensure your safety and comfort. The sleep laboratory at Vincent Pallotti Hospital is fully equipped with a proper bed, clean bedding, restrooms and a kitchenette. It is situated in a secure building with adequate surveillance and alarm system.

A resident technician or a senior researcher will also be present to ensure the smooth running of the equipment. Attempts will be made to familiarise you with the PSG and the electrodes used will be padded and lubricated so as to be as non-intrusive as possible. Electroencephalogram or EEG measures the electrical ("brain wave") activity of your brain. The risks associated with EEG in this study do not differ from those associated with a standard clinical EEG. The primary risk involves the slight possibility of infection at the site of sensor application. Every precaution is taken to prevent infection, and sensors are cleaned after each use.

A team of researchers will be monitoring your sleep at all times. Although unlikely given the non-intrusive nature of the study, you will have access to medical care should you become ill during the experiment.

This study has been approved by the Research Ethics Committee of the Department of Psychology and you should feel free to contact Doctor Kevin Thomas, project advisor (021 6504608) or Ridwana Timol, researcher (0734925349), if you have any concerns about your rights and welfare as a research participant.

**10. What are the possible benefits to you?**

You may or may not personally benefit from participating in this study. Participation in this study may, however, improve your understanding of the effects of sleep on daily, intellectual activities.

**11. If you choose to take part in this research study, will it cost you anything?**

Participating in this study will not cost you anything.

**12. Will you receive compensation for taking part in this research study?**

You will receive financial compensation of the amount of R150 for your participation in the study.

**13a. Can you withdraw from this research study?**

You are free to withdraw your consent and to stop participating in this research study at any time. If you do withdraw your consent, there will be no penalty.

If you have any questions regarding your rights as a research subject, you may phone the Psychology Department offices at 021-650-3430.

**13b. If you withdraw, can information about you still be used and/or collected?**

Information already collected may be used.

**Once personal and performance information is collected, how will it be kept secret (confidential) in order to protect your privacy?**

Information collected will be stored in locked filing cabinets or in computers with security passwords. Only certain people have the right to review these research records. These people include the researchers for this study and certain University of Cape Town officials. Your research records will not be released without your permission unless required by law or a court order.

**15. What information about you may be collected, used and shared with others?**

This information gathered from you will be demographic information, records of your sleep architecture, dream reports, performance on cognitive tests, and scores on the IQ test, personality questionnaire and psychiatric inventory. If you agree to be in this research study, it is possible that some of the information collected might be copied into a "limited data set" to be used for other research purposes. If so, the limited data set may only include information that does not directly identify you. For example, the limited data set cannot include your name, address, telephone number, ID number, or any other photographs, numbers, codes, or so forth that link you to the information in the limited data set.

**16. How will the researcher(s) benefit from your being in the study?**

In general, presenting research results helps the career of a scientist. Therefore, the Principal Investigator and others attached to this research project may benefit if the results of this study are presented at scientific meetings or in scientific journals. This study is being undertaken for the Principal Investigator's honours degree.

**Signatures**

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study;; and how the participant's performance and other data will be collected, used, and shared with others:

Signature of Person Obtaining Consent and Authorization Date

_____________________________________ _______________

You have been informed about this study's purpose, procedures, possible benefits, and risks; and how your performance and other data will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your performance and other data. By signing this form, you are not waiving any of your legal rights.

Signature of Person Consenting and Authorizing                Date

_________________________________________        ____________________



Please indicate below if you would like to be notified of future research projects conducted by our research group:

_______________ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

Method of contact:

Phone number: ____________________________

E-mail address: ____________________________

Mailing address: __________________________________

__________________________________

__________________________________

*Note:* This consent was given to the SLEEP group participants. The other participants completed identical forms, except for minor variations that were relevant to their mode of participation.

Appendix G

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 =** 0.92

**Flexibility:**

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

**Flexibility = 9**

**Originality:**

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

**Originality = 11**

Appendix H

# Instructions for Independent Judges

**Name: _______________________________ Contact Number: ___________________**

Thank you for agreeing to be a judge in my experiment. Here is the pack containing the texts that you will be judging. They were written by different people under different conditions, using a list of 24 words. The spelling, grammar, punctuation and style of the original hand-written pieces have been maintained, as far as possible. They are presented in random order and each is identified by a code. Some of the texts are short narrative stories, while others are just lists of sentences. You need to read through each piece of text and provide two scores for each piece: a **divergent** score and a **convergent** score.

**DIVERGENT** is the extent to which the text is **imaginative, inventive, original, unique, vivid, unusual and unconventional.**

**CONVERGENT** is the extent to which the text is **logical, appropriate, plausible, coherent, lucid, articulate and well-structured.**

The scores you give are your assessment of how well the texts possess these divergent and convergent qualities. The scores you give are percentages, ranging from 0% (not at all present), to 50% (moderately present), to 100% (very present). It is entirely possible that a text can score high on one measure and score low on another. It is also possible that a text can score low for both measures, or high for both measures.

**Please note:**

- Score the texts in the order that they are given to you.
- Do not discuss your scores with anyone else. I am looking for your individual perspective.
- Your initial reaction to the text is usually the most accurate, so it is best not to over-think the scores.
- Take a break when you feel tired or bored.
- Contact me if you have any queries or difficulties.

When you have finished judging the texts, please contact me so I can arrange to get the pack from you and pay you for your work. Once again, thank you very much for your assistance!

Regards,

Anthony Hodge

073 272 1876

Ant.hodge@gmail.com