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Cognitive Offloading among Emerging Adults: The Roles of Working Memory and Metamemory

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This study investigated the relationships between cognitive offloading, working memory (WM) capacity, and metamemory in a sample of 398 emerging adults. Participants completed tasks designed to measure visuospatial and phonological offloading, along with standardised tests for visual (N-back) and auditory (Digit Span) WM capacity and a measure of metamemory (Personal Beliefs about Memory Instrument). The results revealed a significant inverse relationship between WM capacity and the tendency to offload. Specifically, individuals with higher visual WM capacity showed a small but significant negative correlation with visuospatial offloading ($r = -0.18$), while those with higher auditory WM capacity showed a much stronger negative correlation with phonological offloading ($r = -0.609$). This suggests that offloading is a resource-driven process, where those with lower internal cognitive resources are more likely to rely on external aids. In contrast, metamemory played a negligible role in predicting offloading behaviour. The correlations between metamemory and both visuospatial and phonological offloading were either extremely small or statistically non-significant. This finding challenges the hypothesis that offloading is a deliberate, metacognitively guided strategy, instead suggesting that it may be a more automatic response to perceived cognitive demand. The study concludes that while WM capacity is a key predictor of cognitive offloading, an individual's conscious awareness of their own memory abilities plays a minimal role. These findings highlight the importance of cognitive resources over metacognitive awareness in the decision to offload.

Keywords: Cognitive offloading, Working memory, Metamemory, Emerging adults

The digital age has fundamentally transformed how humans acquire, store, and retrieve information. Emerging adults—typically defined as individuals aged 18 to 25 years navigating the transition from adolescence to full adulthood (Arnett, 2000)—are at the forefront of this cognitive revolution. This generation, often referred to as "digital natives," has seamlessly integrated technology into their daily cognitive routines, from using smartphone calendars to manage schedules to employing search engines like Google as an external memory repository (Barr et al., 2015). This strategic use of physical tools and the environment to reduce cognitive demand is known as cognitive offloading (Risko & Gilbert, 2016).

Cognitive offloading is intrinsically linked to the architecture of human cognition, particularly the limitations of working memory (WM). WM, the system responsible for temporarily holding and manipulating information, is a core component of complex cognitive tasks such as reasoning, learning, and problem-solving (Baddeley, 2012). However, its capacity is severely constrained (Cowan, 2010). Cognitive offloading presents a pragmatic solution to this bottleneck; by storing information externally (e.g., writing down a phone number) or outsourcing cognitive operations (e.g., using a calculator), individuals can circumvent their internal WM limitations and enhance overall cognitive performance (Risko & Dunn, 2015). The decision to offload, however, is not automatic. It is a metacognitive process governed by an individual's beliefs about their own memory capabilities—their metamemory.

Metamemory refers to the knowledge and awareness of one's own memory processes, as well as the ability to monitor and regulate these processes effectively (Nelson & Narens, 1990). Effective metamemory enables individuals to accurately assess what they are likely to remember (a judgment of learning, JOL) and then make strategic decisions accordingly, such as choosing to study longer or, crucially, to offload information to an external storage (Metcalfe & Schwartz, 2016). Therefore, the interplay between metamemory and offloading is critical: optimal cognitive efficiency is achieved when offloading decisions are accurately calibrated to the actual limitations of one's internal WM. Poorly calibrated metamemory, however, could lead to either of two suboptimal outcomes: a failure to offload when necessary, resulting in cognitive overload and error, or excessive offloading, which may lead to cognitive underutilization and potential atrophy of internal memory skills (Storm & Stone, 2015).

While cognitive offloading is a ubiquitous phenomenon, emerging adulthood represents a particularly compelling developmental period to study its dynamics. This stage is characterised by significant neurocognitive maturation, including continued development of the prefrontal cortex, which supports executive functions like WM and metacognitive control (Blakemore & Robbins, 2012). Simultaneously, emerging adults face novel and complex cognitive demands in academic, professional, and social domains, making them heavy users of offloading strategies. Understanding how they decide to distribute cognitive labour between internal and external resources is therefore essential. Crucially, it remains unclear how individual differences in WM capacity influence metamemory judgments and, consequently, the propensity to offload. Do individuals with lower WM capacity, who stand to benefit the most from offloading, possess the metacognitive insight to do so adaptively? Or does lower WM capacity impair the metacognitive processes necessary to make effective offloading decisions?

The impetus for cognitive offloading is most frequently attributed to the inherent limitations of internal cognitive systems, particularly working memory. WM, the system responsible for the temporary storage and manipulation of information, is severely capacity-limited (Baddeley, 2012; Cowan, 2010). When task demands exceed these capacity limits, performance declines through increased error rates or slower processing. Cognitive offloading serves as an adaptive strategy to circumvent these limitations. For instance, individuals are more likely to write down a complex set of instructions than to try to remember them internally, thereby freeing up WM resources for higher-order processing (Risko & Dunn, 2015). Empirical evidence robustly supports a negative correlation between WM capacity and the propensity to offload. Individuals with lower WM spans, as measured by tasks like the operation span or n-back, consistently show a greater tendency to rely on external aids compared to their high-span counterparts (Gray et al., 2020; Risko & Gilbert, 2016). This suggests that those who experience the constraints of WM more acutely are more motivated to seek external solutions. However, this relationship is not deterministic. Not all individuals with low WM offload efficiently, and not all with high WM abstain from it. This inconsistency points to the involvement of a secondary, regulatory process that translates the objective state of WM limitations into a subjective decision to act: metamemory.

Metamemory, a subdomain of metacognition, involves both knowledge about how memory works (monitoring) and the strategies used to control it (control) (Nelson & Narens, 1990). Effective offloading is a quintessential metamemory control strategy. It requires an individual to first accurately monitor their likelihood of remembering information without aid (a judgment of learning, JOL) and then to enact a control decision based on that judgment (e.g., choosing to set a reminder or write a note) (Metcalfe & Schwartz, 2016). The critical link here is the accuracy of metacognitive monitoring. An individual must be able to accurately assess their internal state ("I will probably forget this") to make an adaptive decision ("Therefore, I should offload"). Research shows that "saving" information to an external store (a form of offloading) actually enhances memory for the saved information, but only if the decision to save is based on accurate metacognitive monitoring. Conversely, poor metamemory—either in the form of overconfidence (high JOLs for items that will be forgotten) or underconfidence (low JOLs for items that would be remembered)—leads to maladaptive offloading strategies (Storm & Stone, 2015). Overconfident individuals fail to offload when they should, leading to avoidable errors, while underconfident individuals offload unnecessarily, potentially resulting in cognitive laziness or underutilization of internal memory capacity (Gilbert, 2015).

The evolving nature of human cognition in a technologically saturated world is crucial to understand, particularly in the context of cognitive offloading. Emerging adulthood is a pivotal life stage characterised by increasing demands on working memory and metamemory as individuals transition through higher education and into the workforce (Arnett, 2015). The widespread reliance on digital devices during this period presents a unique context for examining the intricate interplay between internal cognitive resources and external technological support. While research has established that cognitive offloading can be adaptive and efficient, potentially freeing up internal resources for higher-order thinking (Sparrow et al., 2011), it has also been linked to detrimental effects, such as reduced long-term memory formation and a diminished sense of internal knowledge (Ward et al., 2017). A significant gap exists in understanding the individual cognitive factors that predict when emerging adults choose to offload and the effectiveness of that choice.

The present study aims to investigate the intricate relationships between working memory capacity, metamemory accuracy, and cognitive offloading behaviour in a sample of emerging adults. Using a controlled experimental task paradigm, we will measure participants' WM capacity, assess the accuracy of their metamemory judgments and observe their choices to offload or rely on internal memory.it is hypothesized that individuals with lower WM capacity will show a greater tendency to offload compared to those with higher capacity; the accuracy of metamemory monitoring will be a significant predictor of offloading behavior, such that more accurate judgements will lead to more strategic and adaptive offloading decisions; and there will be a significant correlation between WM capacity and metamemory accuracy, whereby individuals with low WM but high metamemory accuracy will demonstrate the most efficient use of offloading strategies. The findings will contribute to a deeper understanding of the metacognitive mechanisms underlying offloading and illuminate how emerging adults navigate their cognitive ecosystem in an increasingly technology-saturated world.

Method

Sample

This is a cross-sectional descriptive study aimed at understanding the relation between Cognitive offloading, working memory, and metamemory. The participants were 398 (Male=124, Female=274) emerging adults aged 18 to 26. They were included in the study based on the inclusion criteria of being within the specified age range, having basic Malayalam reading and writing abilities, and not having any neurodevelopmental disorders. Then participants were administered the two tasks of Cognitive offloading, named Visuo-spatial offloading and Phonological offloading tasks developed by the researcher, the N-back test (Wayne Kirchner,1958) and the Digit span test (David Wechsler to measure auditory working memory, followed by the Personal Beliefs about memory instrument (Lineweaver & Hertzog,1998), respectively. The scores obtained for each task were tabularised and analysed to obtain results.

Tasks

The first task of Cognitive offloading was to measure visuospatial cognitive offloading, and the second task was to measure phonological offloading. Both tasks followed the Choice/No choice Paradigm suggested by Risko and Gilbert (2016)

a) Visuo-spatial task: It consists of a Group of pictures arranged in ascending order of number. The first card includes one picture, the second includes two, and it goes up to ten pictures. The task of the participant is to recall the pictures in the correct order and arrange the given cards of pictures in the workspace given. In the first condition, participants have to rely fully on their memory. In the second condition, participants are asked to write down the sequence of pictures on paper. That is a chance for offloading. But in the third condition, the participant has the choice to either depend fully on memory or offload to paper. Each correctly reproduced item gets 1 mark. In each of the three conditions, a total score of 10 will be obtained. The offloading behaviour of participants was observed. The score of cognitive offloading is the difference between the no-choice internal score and the score in the choice condition. Therefore, the greater the cognitive offloading, the higher the score. Scores can be both positive and negative values. Positive scores indicate higher offloading, while negative scores indicate lower offloading. The reliability was measured by calculating Cronbach's alpha to ensure internal consistency of the instrument. The result was found to be 0.64. Face validity was ensured through peer review and respondent review. The content validity was ensured by expert judgment.

b) Phonological Task: This task also has three conditions following the choice or no-choice paradigm. The participants are given 5 pairs of Malayalam letters(vernacular language). They have to replace the first letter with the second letter in the given simple Malayalam words. In the first condition, participants have to rely fully on their memory. In the second condition, they have to write the five pairs of letters. In the third condition, participants have the choice to either recall the letters from memory or offload them and complete the task. Each correctly reproduced item gets 1 mark. In each of the three conditions, a total score of 10 will be obtained. The offloading behaviour of participants was observed. The score of cognitive offloading is the difference between the choice internal score and from choice condition score. Therefore, the greater the cognitive offloading, the higher the score. Scores can be both positive and negative values. Positive scores indicate higher offloading, while negative scores indicate lower offloading. The reliability was measured by calculating Cronbach's alpha to ensure internal consistency of the instrument. The obtained value is 0.54. Face validity was ensured through peer review and respondent review. The content validity was ensured by expert judgment.

c) Personal beliefs about memory instrument: By Lineweaver & Hertzog (1998) consists of 51 items in the 5-point Likert scale format. Designed to assess an individual's subjective perceptions and beliefs about their own memory abilities and functioning in everyday life. The subscales are Global memory ability, Relative standing ratings, Retrospective change, Prospective change, control and Specific memory ability. The reliability of the scale was found to be 0.64.

Result and Discussion

Table 1 shows Pearson's coefficient of correlation between visual working memory, visuo-spatial offloading, and metamemory

Variable	M	SD	1	2
1. Visual working memory	7	1.4		
2. visuo-spatial offloading	1.9	2.1	–0.18*	
3. Metamemory total	178.4	26.2	0.107*	0.01*

Visual working memory (M = 7.0, SD = 1.4) showed a small, but statistically significant negative correlation with visuospatial cognitive offloading (r="0.18, p<.05). It also had a small, statistically significant positive correlation with specific memory ability (r=0.14, p<.05).

Visuospatial cognitive offloading (M = 1.9, SD = 2.1) exhibited very small, though statistically significant, positive correlations with several metamemory and memory-related variables, including metamemory total (r=0.01,p<.05), retrospective change (r=0.012,p<.05), prospective change (r=0.013,p<.05), control (r=0.003,p<.05), and specific memory ability (r=0.001,p<.05). These correlations, while statistically significant, are very close to zero and likely represent negligible practical effects.

Table 2: Showing the correlation, Pearson's coefficient of correlation between auditory working memory, phonological cognitive offloading, and metamemory

Variable	M	SD	1	2
1. Auditory working memory	6.03	1.27		
2. Phonological offloading	3.39	2.82	–0.609*	
3. Metamemory total	178.4	26.2	0.081*	-0.79*

The correlation matrix revealed several significant relationships among the variables. As shown in the Table, phonological cognitive offloading was negatively correlated with auditory working memory (r = -0.609, p < .05).

Table 3: Showing ANOVA of regression of Visuo-spatial offloading with visual working memory and metamemory

Source	Sum of squares	Degrees of freedom	Mean sum of squares	F	Sig
Regression	66.73	2	33.36	7.32	0.001
Residual	1799.01	395	4.55		
Total	1865.74	397			

Table 4 shows the regression coefficient and t-value for Visuo-spatial offloading

Factors	Regression coefficient	Standard error	Standardised regression coefficient	t value	Sig
N back	-0.29	0.07	-0.19	-3.81	0.00
Metamemory	0.003	0.004	0.034	0.68	0.491

A one-way ANOVA of regression was conducted to examine the relationship between Visuospatial Offloading and two predictor variables: N-back and Metamemory. The overall model was statistically significant (F(2, 395) = 7.32, p = 0.05), indicating that the combination of N-back and Metamemory was a significant predictor of Visuospatial Offloading. The model explained a significant portion of the variance in Visuospatial Offloading (R^2 = 0.035, calculated from the Sum of Squares for Regression divided by the total sum of squares, 66.73/1865.74). Further analysis of the individual regression coefficients revealed that N-back was a significant negative predictor of Visuospatial Offloading (â = -0.19, t (395) = "3.81, p < 0.001). This suggests that as an individual's Visual working memory increases, their reliance on visuospatial offloading decreases. Conversely, Metamemory was not a significant predictor of Visuospatial Offloading (â = 0.034, t(395) = 0.68, p = 0.491).

Table 5: Showing ANOVA of regression of Phonological offloading with visual working memory and metamemory

Source	Sum of squares	Degrees of freedom	Mean sum of squares	F	Sig
Regression	1179.53	2	589.76	116.98	0.00
Residual	1991.32	395	5.04		
Total	3170.85	397			

Table 6 shows the regression coefficient and t value for Phonological offloading

Factors	Regression coefficient	Standard error	Standardised regression coefficient	t value	Sig
Digit span	-1.34	0.08	-0.60	-15.16	0.00
Metamemory	-0.003	0.004	-0.30	-0.74	0.46

The ANOVA for the regression model was statistically significant, F(2, 395)=116.98, p<0.05. This indicates that the model as a whole makes a significant prediction of the outcome variable. The combined predictors explained a substantial portion of the variance in Phonological Offloading, with a coefficient of determination (R2) of 0.37 (calculated by dividing the Sum of Squares for Regression by the Total Sum of Squares: 1179.53 / 3170.85).

An examination of the individual predictors revealed that Digit Span was a significant negative predictor of Phonological Offloading (â = -0.60, t(395) = "15.16, p < 0.05). This finding suggests that as an individual's Digit Span—a measure of their Auditory memory capacity—increases, their use of phonological offloading tends to decrease. In contrast, Metamemory was not a significant predictor of Phonological Offloading (â = -0.30, t(395) = "0.74, p = 0.46).

Discussion

The purpose of this study was to examine the relationships among Cognitive offloading, working memory, and metamemory. The results of the correlational analyses provide insights into the interplay of these constructs. The statistically significant, albeit small, negative correlation between visual working memory and visuospatial offloading suggests that individuals with higher visual working memory capacity might tend to engage slightly less in visuospatial offloading. However, given the small magnitude of this correlation (r = -0.18), this relationship appears to be weak. It is possible that while offloading can reduce cognitive load, for highly visual tasks, a strong internal working memory might naturally reduce the need for external aids in some contexts.

The correlation analysis revealed several key findings. The statistically significant, albeit small, negative correlation between visual working memory and visuospatial cognitive offloading suggests that individuals with higher visual working memory capacity might tend to engage slightly less in visuospatial cognitive offloading. However, given the small magnitude of this correlation, this relationship appears to be weak. It is possible that while offloading can reduce cognitive load, for highly visual tasks, a strong internal working memory might naturally reduce the need for external aids in some contexts. The minimal, yet statistically significant, correlations between visuospatial cognitive offloading and the metamemory and specific memory ability variables are noteworthy. While statistically significant due to a likely large sample size, the practical significance of these correlations is negligible. This suggests that visuospatial cognitive offloading, as measured in this study, has a minimal linear relationship with individuals' overall metamemory beliefs or specific memory abilities. This indicates that offloading is a distinct strategy, largely independent of broader metacognitive awareness or underlying memory strengths, or that its impact is more nuanced and not captured by simple linear correlations. The strong negative correlation between auditory working memory and phonological cognitive offloading suggests that individuals with higher auditory working memory capacity tend to engage less in phonological cognitive offloading. The negative correlation between metamemory total and phonological cognitive offloading further supports the idea that effective internal metacognitive processes may reduce the need for external cognitive aid.

While these findings provide valuable insights into the relationships among these cognitive and metacognitive constructs, it is important to note that correlational data do not imply causation. This finding aligns with the general understanding of cognitive load theory, which posits that individuals with greater cognitive resources are better equipped to handle tasks internally without relying on external aids (Sweller, 1988). Regression analysis showed that visual working memory is a significant predictor of visual offloading. Also, auditory working memory is a powerful predictor of an individual's reliance on phonological offloading. The significant negative relationship suggests a direct trade-off: individuals with greater internal cognitive resources for holding and manipulating auditory-verbal information are less likely to rely on external strategies to do so. This finding aligns with the cognitive offloading theory, which posits that people with limited cognitive resources, or those facing a high cognitive load, will externalise cognitive processes to reduce internal demands. For example, a person with a low working memory might be more inclined to repeat a phone number out loud or write it down rather than trying to hold it in their head.

The non-significant finding for Metamemory is interesting. It implies that an individual's awareness and knowledge of their own memory processes do not directly influence their decision to offload cognitive tasks in a visuospatial context. This suggests that the decision to offload may be driven more by the immediate availability of cognitive resources than by a strategic, metacognitive evaluation of one's own memory abilities. People tend to offload more difficult items selectively. While metacognition is involved in judging difficulty, the immediacy and adaptivity of offloading to the specific moment-to-moment difficulty suggest a responsive system geared toward optimising the current allocation of cognitive resources, rather than a broad, strategic evaluation of one's memory ability across all tasks (Hu Z, et al., 2019). The decision to offload serves the immediate goal of reallocating limited cognitive resources for current or upcoming demands, making it a resource-management strategy driven by the immediate cognitive environment (Runge et al., 2019).

The act of visuospatial offloading may be an automatic or unconscious process, rather than a deliberate strategy informed by an individual's metacognitive knowledge. Conversely, the lack of a significant relationship between metamemory and phonological offloading is a noteworthy finding. Metamemory, or the knowledge and awareness of one's own memory processes, did not predict whether or not an individual would offload phonological tasks. This suggests that phonological offloading may not be a deliberate, metacognitively guided strategy, but rather a more automatic or habitual response to a perceived cognitive demand. The decision to offload may happen at a preconscious level, triggered by the brain's internal monitoring of resource availability, rather than by a conscious evaluation of one's own memory strengths and weaknesses. Offloading behaviour occurred in a way that often compromised subsequent internal memory, and this behaviour appeared to be less of a consciously selected strategy and more of an automatic response to external affordances. The mere availability of the external information (the model pattern) seemed to trigger the offloading behaviour, suggesting a rapid, less deliberative mechanism than a full metacognitive cost-benefit analysis (Morgan et al., 2009). The ease of externalising the information made it the default strategy.

In conclusion, these findings highlight the critical role of working memory capacity in determining the use of phonological offloading, while suggesting that metacognitive awareness may play a minor or no role. The results support the idea that offloading is a dynamic process heavily influenced by the immediate availability of cognitive resources.

Conclusion

The purpose of this study was to examine the relationships among cognitive offloading, working memory, and metamemory. The findings revealed distinct patterns depending on the modality of cognitive offloading investigated. The research found a significant inverse relationship between working memory capacity and cognitive offloading, suggesting a trade-off between internal cognitive resources and the use of external aids. Specifically:

- Visuospatial Domain: A small but statistically significant negative correlation (r=".18) was found between visual working memory and visuospatial offloading. This indicates that individuals with higher visual working memory capacity tend to offload less.
- Phonological Domain: A strong negative correlation (r=".609) was observed between auditory working memory and phonological offloading. This relationship was much stronger than in the visuospatial domain, highlighting that individuals with better internal resources for auditory-verbal information are far less likely to externalise those processes.

In contrast, the study found a minimal or negligible role for metamemory in predicting cognitive offloading. The correlations between visuospatial offloading and metamemory variables were extremely small, despite being statistically significant. This suggests that the decision to offload a cognitive task may be an automatic, resource-driven process rather than a deliberate, metacognitively-guided strategy.

The results of this study underscore the critical role of working memory capacity as a key determinant of cognitive offloading, particularly in the phonological domain. The findings support the idea that offloading is a dynamic process influenced more by the immediate availability of cognitive resources than by a strategic, metacognitive evaluation of one's own memory abilities. While working memory and cognitive offloading appear to operate in a direct inverse relationship, metamemory seems to be a separate, yet equally important, construct. It is strongly linked to overall cognitive and memory performance but has a minimal linear relationship with the use of external cognitive aids. The findings suggest that offloading may be a distinct, resource-driven strategy that operates independently of broader metacognitive awareness. Future research should explore potential non-linear relationships, moderating factors, or causal pathways using experimental or longitudinal designs to further illuminate the complex interplay among these cognitive constructs.

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