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Review Paper

Cognitive Offloading: Systematic Review of a Decade

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ABSTRACT

Cognitive offloading refers to the use of physical action to alter information processing requirement of the given task. Offloading can be done either internally or externally. We have been included cognitive offloading through external tools related papers. Cognitive offloading is applied aspect of Extended Mind Thesis (EMT). EMT is applicable to human beings, technological & cognitive artefacts and self & group. Deliberation points on EMT has been found: what is cognitive and how to differentiate causal coupling from constitutive. Necessary deliberations either acceptance or rejections till date has been included (from 2009 onwards) in this paper. EMT can also be applied to the web, known as web based cognitive offloading where web is collection of external representations. Interaction of mind with artefact is also included in this paper till date to enrich knowledge as mind artefact interaction is one of the forms of cognitive offloading. Empirical studies of cognitive offloading found in literature which revolve around the questions of why one engages in cognitive offloading despite of good memory. For poor memory or brain damage, external tools are good compensatory tool. This paper specifically deals with advances in technological & cognitive artifacts and at the end, future directions in cognitive offloading has been suggested.

Keywords: *Extended Mind Thesis (EMT), cognitive offloading, web, short-term memory*

Cognitive offloading is cognitive unloading technique through a medium. Here medium works as a storage of offloaded material that can be accessed whenever required. Cognitive offloading is one of the applications of extended mind thesis. Clark & Chalmers (1998) proposed the idea of active externalism which states mind does not limit to our cutaneous boundary but get extended into the environment. They discussed this phenomenon with character of "Otto and Inga where Otto was suffering from memory loss and Inga was having intact memory. Otto keeps notebook (this is an example of being part of ambient surrounding) which function for Otto as a function of biological memory like a normal person (Inga). So, this way functionally similar cognitive and non-cognitive system meet, and they overall become cognitive system. Cognitive extension has different forms be it naturally extended cognitive system, extended cognitive system with technological resources, or socio- cultural extended cognitive system (Wilson & Clark, 2009). Cognition can be distributed across heterogeneous systems combining neural, bodily,

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social and technological resources (Michaelian & Sutton, 2013). Technological resources is key to go through this paper. As physical tool increases physical capacity and kitchen tools increase digestive capacities, same way capacity of mind gets extended by cognitive tools. This increased capacity is exceptional case of adaptive phenotypic plasticity (Sterelny, 2010). Phenotypic plasticity is the extent of same organism of showing variance of attributes in different conditions. This becomes an adaptive strategy for living in varying environments as long as the plastic response is sufficiently fast and accurate, and is not too costly (Xue & Leibler, 2018). Extended mind is known by variety of names like: active externalism, environmentalism, vehicle externalism (P. R. Smart, 2012; Steiner, 2010; Wilson & Clark, 2009).

Deliberations on EMT:

Adams and Aizawa (2009), strong opponents of EMT started quibbling by addressing the fallacies maintained by transcranialist, else in their opinion transcranialism and intra-cranialism would remain only terminologically individuated. Qualm presented by them if it is cognition or mind, define theoretically what would be going under extended cognition or extended thesis, which had never been earlier to traditional cognition (Adams & Aizawa, 2009; Rowlands, 2009). Two prominent issues concerning EMT are: what would cognitive so that differentiation between internal cognitive and external cognitive can be done and another one would confusing causal coupling relation with constitutive relation (Adams & Aizawa, 2009; Arnau et al., 2014; Kaplan, 2012; Maeda, 2012; Piredda, 2017; Toro, 2018; Walter, 2010; Wheeler, 2011). Coupling relation shows causation whereas constitutive means an external object becomes the part of internal cognition (Adams & Aizawa, 2010; Clark et al., 2012; Menary, 2010b; Piredda, 2017; Sprevak, 2010; Toro, 2018). Kaplan (2012) offered mutual manipulability account to differentiate boundaries of cognition.

Criteria for cognitive is defined as any process is related with information processing and make it available the earlier unavailable information to subject in representational state (Rowlands, 2009). Cognitive processes involve manipulation of non-derived content which operates exclusively on specific principles within the brain (Adams & Aizawa, 2009; Clark, 2010). The rejections didn't limit here that get extended further on other ground as well, whether internal and external cognitive processes are same (like manipulation, transformation, semantic level processing in internal memory is same for externally offloaded memory ?), upto what limit internal cognition works and external cognition begins and what constitute criterion of cognitive itself (Clowes, 2013; Rowlands, 2009).

Other rejections have been reported by Rupert on the ground of internal and outer cognitive differentiation which will cost higher to cognitive psychology without adding any value to its subject matter and at the end whatever the progress has been made in this field will confined to coupled system study (Wilson & Clark, 2009). During the same year, Sprevak (2009) shed the light on extended cognition and reported how functionalism could be inevitable part of extended cognition and this manner it could be more radical. Originally, Clark has addressed functionalism of EMT on the coarse grain analysis. Coarse grain analysis refers to comparing two processes on the shallow level of functioning, but it has been further rationalized on the fine grain analysis (Rodríguez, 2011). Fine grain analysis refers to analysing deeper level of processing for example on the neuron basis.

As this functionalist version of EMT has been objected on coarse grain analysis vs. fine grain analysis (Milojevic, 2020).

Year 2010 onwards views came to revise EMT a bit. Menary (2010a) has addressed this approach as cognitive integration by focusing more on complementarity principal than parity. Now predictive processing is new mark of cognitive (Kersten, 2022). Predictive processing is reducing difference by mind between reality and prediction.

Waves of EMT: 1st wave supports parity principle whereas 2nd wave supports complementarity principle. Parity principle talks about functional similarity while in complementarity, it augments one's cognitive capability. 2010 onwards a 3rd wave deliberation has been started by the Paper of Sutton (2010). 2nd wave of extended mind has been objected on the ground that socio-cultural or technological artefacts only increases internal capacity rather than transmuting the internal representation (Kirchhoff, 2012). So, third wave also need to be considered if extended mind has to be understood, in terms of cognitive extension, parity principle will be the key (Loughlin, 2020). Vold & Schlimm (2020) has objected Adams and Aizawa's non derived content by giving the example of external symbols of mathematics which are not derived but external in nature.

Web and EMT:

Simultaneously, when debate on extended mind thesis was going on, web based cognitive extension was also being discussed. It was the product of curiosity of different psychologists whether metaphor of EMT can be applied to the web, as it follow the criteria of availability, trust, accessibility and conscious endorsement (P. R. Smart et al., 2010). Web based content can be part of extended mind, if factual contents can guide our thought, action and somehow supports cognition (P. R. Smart, 2012).

Web is transformative collection of external representation. Its major advantage is simultaneously different person can access that representation in the dynamic environment, this way same cognitive state can be shared (Halpin et al., 2013; P. R. Smart, 2012). But the biggest issue in internet use is blur boundary between what the user knows and what the internet knows (P. Smart, 2017; Ward, 2013). P. Smart has been elaborated that web is a resource, identified by uniform resource identifier (URI) and accessed by HTTP. Web extended mind is a systematic organization that exist as both web based system and extended cognitive system. Web is basically application of internet. The issues in applying the extended mind criteria to the internet by P. Smart (2017).

Availability: Clark talked about availability of resource though Otto's notebook. As book and information intertwined together. Whenever notebook is taken, information is also within, but same is not applicable in internet case, having computer or mobile do not provide information unless equip with internet connectivity. So, resource availability and information availability both are different in the web extended mind case.

Trust: web pages are editable. Due to simultaneous access by different user doesn't it quite difficult to trust all time? Accessibility or portability. Accessibility, one of the main criteria of thesis, spatial physical proximity should be the criterion of cognitive integration rather than indirect connect with other resources and data base. To resolve this issue a few dimensions have been suggested along which user and online information varies. Those dimensions are sort of and intensity of information, flow between an agent and technological artefact, accessibility of information resources, the permanence of agent artefact relation, amount of faith an agent puts into an online information, asinmuch of transparency-in-use that is encountered, easily comprehensive information, amount of personalization that has been undertaken due to interaction, extent of cognitive transformation introduced. The

stronger the position on these dimensions, the more easier to count agent artefact interaction to the extended one.

Mind and Artifact: There are different varieties and complexities in both the type of cognitive artifacts and cognitive profile of human agents. Cognitive artifact can be anything which is having representational function and somehow affecting cognitive performance. Interaction of artifact and agent's mind can be better understood through "Extended Mind Theory" (Heersmink, 2015). As there are two lines of thoughts under extended mind theory: parity principal and complementarity principal. Heersmink (2015) explained that complementarity based approach is quite progressive and better way to understand varieties and reasons of individual differences in the interaction of artifact use with mind. Heersmink comprehensively explained the flow of information between humans and cognitive artifacts. He defined three overlapping levels of information flow. They are monocausal (a one way information flow like using clock or map), bicausal (two side information flow like note posting) and reciprocal information flow (when artefacts become part of ongoing task like while writing academic paper solving a maths problem) . Artifact use is dependent on several dimensions (Heersmink, 2012; Sterelny, 2010). Dimension indicates degree and functional relationship between agent and external resources as a hunch about explanation of the coupling relation.

Empirical investigation of cognitive offloading is now on boom. During last decade below mentioned empirical investigations were done:

Author	Paper title	Task, Sample	Design	Findings
Risko & Dunn (2015)	Storing information in-the-world: Metacognition and cognitive offloading in a short-term memory task.	Short-term – memory (Forward Span) Task, 34 participants	2(no choice internal versus no- choice external) vs X 5(set size: 2vs4vs6vs8) within participants design	Accuracy is the reason for cognitive offloading behaviour
Flusberg & Ramos (2018)	Saving-enhanced memory in the real world.	Memorization of two lists of common nouns, 50 participants	2 (trail type: save vs. shred) X 2(list type: list A vs. list B) within participants design	Effect of memory offloading is not format specific in nature.
Cherkaoui & Gilbert (2017)	Strategic use of reminders in an 'intention offloading' task: Do individual with autism spectrum conditions compensate for memory difficulties?	Intention offloading task, Prospective and Retrospective memory questionnaire, Metacognition s questionnaire, Cognitive failures questionnaire and Implicit confidence measure. 28 adults participants (4 females) with Autism spectrum condition and 24 (6 females) neurotypicals	2(memory load: 1target, 3target) within participants X 2(group: autism spectrum condition, neurotypicals) between participants design.	Performance of subject's with autism spectrum condition (ASC) was significantly poorer than the neurotypical group in phase 1 where participants had no option for offloading. ASC group failed to compensate for deteriorated performance.

Landsiedel & Gilbert (2015)	Creating external reminders for delayed intentions: Dissociable influence on "task- positive" and "task-negative" brain networks.	Intention offloading task while undergoing functional magnetic resonance imaging (fMRI). 15 right handed participants.	5(conditions: no intention vs. offload 1 vs. offload 3 vs. no offload 1 vs. no offload 3) within participants design.	A clear functional distinction between task-positive and task-negative brain networks was found.
Gilbert (2015)	Strategic offloading of delayed intentions into the external environment.	Intention offloading/ Non offloading task, Lexical decision task, Event-based task, Time- based task, Naturalistic PM task, 1701 participants.	2(group: no interruption, interruption) X2(target condition: intention offloading, non offloading)X 4(task type: intention offloading/ no offloading task, lexical decision task, event based prospective memory, time based prospective memory) mixed design	When participants used their internal memory, their ability to fulfil prospective works deteriorated due to intrusion.
Storm et al. (2017)	Using the Internet to access information inflates future use of the internet to access other information.	Sixteen Trivia questions on the topic of history, sports and pop culture from a trivia book. 100 participants.	3(conditions: internet vs. memory vs. baseline) X 2(question set: easy trivia vs. difficult trivia) X2(device: computer, iPod) between subjects design.	Using internet as instruction repertoire affects to what extent internet will be used in the future.
Eskritt & Ma (2014)	Intentional forgetting: Note-taking as a naturalistic example.	Concentration game, 94 and 36 participants in two experiments respectively	4(group: recall note taking vs. recall study vs. recognition note taking vs. recognition study) X 2(experimental decks: one vs. other) between subjects design was used.	Note-taking group remembered significantly more location information than other group and note takers did not show proactive interference while playing concentration repeatedly.
Kelly & Risko (2019a)	Offloading memory: serial position effects.	Word list presentation in auditory form by making position constant in 1st experiment and randomized position of words in 2nd experiment. 64 Participants	3 (serial position: first vs. middle vs. last) X 2 (offloading vs. no offloading) mixed design	Offloaded items showed recency effect than primacy effect. Better recall of items at the end is recency effect and better recall of items at the starting position is primacy effect.

Weis & Wiese (2019)	Problem solvers adjust cognitive offloading based on performance goal.	Extended rotation task, 100 participants,	three-factorial design with the within-participants factors handedness of the working stimulus with respect to the base stimulus (same, opposite) X angle (0°, 60°, 120°, 180°), and between-participants factor performance goal (accuracy, speed)	Participants adjusted offloading behaviour according to the goal either speed or accuracy of the cognitive task.
	Offloading memory leaves us vulnerable to memory manipulation.	Given to-be-remembered list of words. 75 participants	Mixed design. The manipulation of the insertion of a word (no word is added to lists 1-3; a word is added to list 4) is within subject. The manipulation of the position of the inserted word (1st vs. middle) is between subjects. There were 4 lists of words and associated "target" words (i.e., words that are added to the offloaded list when it appears in the 4th position). These lists were counterbalanced across subjects across positions so that each list appeared in each position equally often.	If offloaded information is manipulated, it will be rarely noticed and will be easily stored into participant's biological memory.
Kelly & Risko (2019b)	The isolation effect when offloading memory.	Recalling of list of words, 50 participants	2 (offloading vs. no offloading) X 2 (isolated vs. control) within-participants design	Participant's recall was poor when able to offload the to-be-remembered information and greater recall for isolates than control.
Bocanegra et al. (2019)	Intelligent problem solvers externalize cognitive operations.	Click and Drag version of Raven's Test and 211 and 184 participants respectively in experiment 1 and experiment 2.	3(course: introduction to psychology vs. introduction to research methods vs. inferential statistics) between subjects X 2(task type: conventional raven advanced progressive matrices vs. click and drag raven advanced progressive matrices) within subjects design.	Click and drag version of the test is better at predicting academic success of university students.
Weis & Wiese (2018)	Speed consideration can be of little concern when	Mental rotation paradigm, 150 participants	2(handedness: same vs. different) X4(angle: 0, 60,120, 180 degree) X 3(locus of	Offloading behaviour is not always provoked by limitation of

	outsourcing thought to external devices.		rotation: forced internal, forced external, choice) mixed design.	time but to reduce memory load.
Boldt & Gilbert (2019)	Confidence guides spontaneous cognitive offloading.	435 participants, Delayed Intentions Task	2(group: instructed offloading, spontaneous offloading) X 2(phase: 1, 2) X 2(confidence type: prediction, post diction) mixed design	Participants set more reminders when participants were less confident about their internal memory.
Redshaw et al. (2018)	Development of children's use of external reminders for hard to remember intentions.	Delayed intentions Task, 63 children	2(condition: 1 target, 3target) X 2(phase: 1,2) within subjects X 3(age: below 9 year, 9-11 year, above 11 year) between subjects design.	Knowledge of metacognition is also possessed by primary children but only older adults can translate it into reminder setting.
Soares & Storm (2018)	Forget in a flash: a further investigation of the photo-taking-impairment effect.	Photo taking task, 42+41 sample in each experiment.	In both experiments, 3(condition: observe, camera, snapchat) within factors design was used.	To take photo impairment effect was also found when participants deleted that manually and did not expect to have access the photos. So, offloading may not be the sole mechanism for photo taking impairment effect.
Henkel (2014)	Point-and- shoot memories: The influence of taking photos on memory for a museum tour.	Photo taking task, 28 undergraduates	2(photography vs. observed) X 3(observed vs. photographed vs. not part of tour) within participants design.	Subject's remembered less objects and details about the objects and the object's location than if they only observed the objects and did not photograph them.
Berry et al. (2019)	Cognitive offloading: structuring the environment to improve children's working memory task performance.	Working memory task, forward digit recall, backward digit recall, corsi block. 166 participants	3(condition: ordered arranged blocks, random arranged blocks) X2(working memory ability: high, low) mixed design.	Despite performing better in the ordered condition,children with low working memory ability did not rate the ordered arrange ment as easier, nor did they choose an ordered arrangement when given the opportunity to do so

Scarampi & Gilbert (2020)	The effect of recent reminder setting on subsequent strategy and performance ina prospective memory task.	220 participants, intention offloading task, arithmetic verification test	2(phase: 1,2) X 2(conditions: no reminders, forced reminders) within participants design.	Earlier stage reminder setting did not affect memory ability but increases later on probability of setting reminder.
Hu et al. (2019)	A role for metamemory in cognitive offloading.	27 participants in each experiment, cue-word task	3 conditions (learning vs. forced recall vs. free choice) X 2 (whether the word pair was saved during learning: saved vs. unsaved)X2 (whether participants asked for help in the free- choice test: ask-for- help vs. answer-by- themselves) X 2(confidence type: with-hint vs. without-hint)	Evaluation of metacognition about memory performance is related with cognitive offloading.
Gilbert et al. (2020)	Optimal use of reminders: metacognition , effort and cognitive offloading.	216 participants, optimal reminders task	3(trails: forced internal vs. forced external vs. choice between internal or external) X 2(condition: choice vs. no choice) within participants design.	Participants showed bias (systematic) towards reminder setting even in the condition of choosing at optimal level with financial incentive. Metacognitive underconfidence had been found responsible for this bias.
Dunn & Risko (2016)	Towards a metacognitive account of cognitive offloading.	26 participants, frame-word rotation task	One factor (array type: rotated word- rotated frame, rotated word- upright frame, upright word- rotated frame, upright word- upright frame) within participants design	Metacognitive belief is responsible for the selection of strategy in regarding expected performance and effort required for particular task.
Grinschgl et al. (2020)	Interface and interaction design: How mobile touch devices faster cognitive offloading.	172 participants, pattern copy task, two visual working memory tests, corsi block task.	2 (responsivity: high vs. low responsivity condition) X 2 (device control: touch vs. mouse condition) between-participants design	Metacognitive evaluation can be affected by interface and interaction design both.Those participants offloaded more when their device was responsive and used touch function.

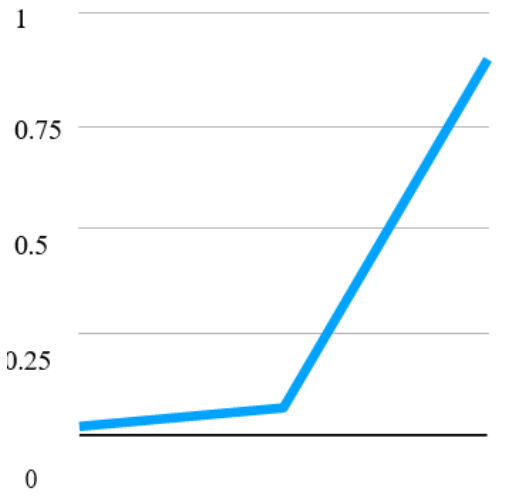
Morrison & Richmond (2020)	Offloading items from memory: individual differences in cognitive offloading in a short-term memory task.	114 participants, Short-term- memory task.	2(instruction: no choice vs. choice) X5(load: 2,4,6,8,10) within subjects design	When memory load is high, cognitive offloading improves performance but participants with poor memory ability don't have greater tendency to offload.
Risko et al. (2014)	Rotating with rotated text: A natural behaviour approach to investigating cognitive offloading.	20 participants, letter naming and reading stimuli task	3(set size: 1,5,15) X3(angular deviation: 0,45,90) within participants design	Effort is valuable factor in deciding which resource to use either internal or external
Arreola et al. (2019)	Does the use of tablets lead to more information being recorded and better recall in short- term memory tasks?	23 participants, pairs of words task	2(external medium: paper vs. tablet) between factor X 3(set size: 2,4,6) within factor design	Offloading behaviour reduced for tablet comparatively to paper.
Weis & Wiese (2022)	Know your cognitive environment! Mental models as crucial determinant of offloading preferences.	323 participants, Airthmetic task and Social task.	2(task: arithmetic vs. social) X 2(environment: agents vs. apps) X 2(mental model: task unspecific agent vs. task specific app beliefs)	Task specific data plays important role to change offloading behaviour, and It would be more applicable to apps comparatively to humans or robots. So, mental model (stored belief) is crucial approach to offloading cognition preferences.
Walsh & Anderson (2009)	Strategic nature of changing your mind.	41 participants, three structural type multiplication problem	2(condition: calculator vs. mental) X 2(problem type: 28NNx10 vs. 56NxNN vs. 28NNxNN	People assess which strategy to choose according to the given context.
Virgo et al. (2017)	Are you sure you are faster when using a cognitive tool?	139 participants, tool use vs. no tool use action paradigm with addition task	2(phase: mental calculation vs. calculator use) X 3(conditions: real performance, perceived performance, choice) within participants design	Subject's estimation of time was overrated in calculator use compared to mental calculation. This result shows tool related biases.

Weis & Wiese (2019a)	Using tools to help us think: actual but also believed reliability modulates cognitive offloading.	126 participants, extended mental rotation paradigm.	6(reliability: 50%, 60%, 70%, 80%, 90%, 100%) X 2(handedness: same, different) X 2(angle:60,120) within participants and 3(belief: naive, congruent, incongruent) between participants	The extent of cognitive offloading depends upon false metacognitive belief and utility maximization
Storm & Stone (2015)	Saving-Enhanced Memory: The Benefits of Saving on the Learning and Remembering of New Information.	Pdf saving and remembering task, 48 participants.	2(trial type: save, no save) X 2(condition: reliable, unreliable) X 2(condition: 8word, 2word) within participants design.	Saving information frees space for learning new material, but if and only if saving process would be reliable.
Mueller & Oppenheimer (2014)	The pen is mightier than the keyboard: Advantages of longhand over laptop note taking.	TED Talks topic, Prose passages on bats, bread, vaccines and respiration. 327 participants	2(condition: laptop vs. notebook) between subjects X 2(lecture: factual recall questions vs. conceptual applications question) within subjects design.	From learning perspective, note taking would be beneficial, and taking notes on laptop was useful for verbatim recording.
Sparrow et al. (2011)	Google Effects on Memory: Cognitive Consequences of Having Information at Our Fingertips	106 and 28 participants, modified stroop task, recognition task, recall task.	For 1st experiment, 2(level of questions: easy, difficult) X2(Blocks of questions: 1,2) between participants. For 2nd experiment, 2(statement: save, erase) between participants design. For 3rd experiment, 3(conditions: entry saved, entry saved into FACTS, entry erased) within participants design.	During tough questions, participants moved to computer. And when it was surety about future access of information, their recall was better for information stored place than recall content itself.
Ferguson et al. (2015)	Answers at your fingertips: Access to the internet influences willingness to answer questions.	100 participants, cognitive reflection test, general knowledge questions of varying levels of difficulty.	2(list of questions: block 1 vs. block 2) X 2(condition: internet access vs. no internet access) X 3(condition: block 1 vs. block 2 vs. feeling of knowing questions) within participants design.	Due to availability of internet, willingness to answer decreased of participants and feeling of knowing also decreased.

Fisher et al. (2015)	Searching for explanations: How the internet inflates estimates of internal knowledge.	558 participants, List of questions used in different experiments	Experiment 1: 2(conditions: internet vs. no internet) between participants X2(phase: induction vs. self assessment) within subjects.Experiment 2: 2(conditions: internet vs. no internet) between subjects X 3(phase: induction vs. self assessment vs. preinduction self-assessment) within subjects design.	Online repository of information leads to perception of more knowledge in one's self head, (but mistakenly).
Macias et al. (2015)	Memory Strategically Encodes Externally Unavailable Information	Checking of subject's memory retention, 150 subjects	2(condition: lookupable vs. nonlookupable) X 2(savviness: single search vs. multiple searches) within -subjects participants design	Metacognitive knowledge is also responsible for online searching also.
Lu et al. (2020)	Offloading information to an external store increase false recall.	40 Participants in both conditions, 20 items word list for encoding, retention and recall.	2(conditions: offloading vs. no- offloading) within participants design was used.	Storing information externally, increase chances of recall of wrong similar items.
Sachdeva & Gilbert (2020)	Excessive use of reminders: Metacognition and effort-minimisation in cognitive offloading.	208 participants, Intention offloading task and metacognitive measure.	2(condition: reward vs. no reward) between subjects design.	Financial reward is also factor of cognitive offloading.
Engeler & Gilbert (2020))	The effect of metacognitive training on confidence and strategic reminder setting.	116 participants, Optimal reminders task.	2(condition: experimental group with metacognitive feedback vs. control group with no such feedback) between subjects design.	This study was designed to check if metacognitive training has an effect on metacognitive judgement accuracy and strategic reminder setting. In result, it was found that feedback can improve accuracy but biological memory ability being unaffected.
Grinschgl et al. (2021)	Consequences of cognitive offloading: Boosting performance but diminishing memory.	172 participants in all the three experiments, Pattern copy task, Memory test, Visual patterns test, Corsi blocks test.	2(temporal lockout condition: lockout vs. no lockout) between subjects design was used.	People prefer internal memorisation due to later negative effect of offloading on memory. Offloading

				depends on task at hand.
Armitage & Redshaw (2022)	Children boost their cognitive performance with a novel offloading technique	97 participants, used maps to search for stickers hidden under white pots	8(age: 4*5*6*7*8*9*10*11, between)X2(maps: aligned*misaligned, within) mixed design was used.	As age increases, children develop offloading strategies thus improvements on unaided performance in children has been seen.
Blaskovits et al. (2022)	Misplacing memory: examining the phenomenon of cognitive offloading during an officer-involved use of force scenario	50 participants, demo graphics, heart rates, standard use of force report, StressVest and Body worn cameras	2(Conditions: body worn camera*no body worn camera) between subjects design was used	Police officers who were given opportunity to offload their event details on BWC, chose not to do so.
Peper et al. (2022)	Differential benefits of prospective memory reminders depending on cognitive load	193, 151 and 87 participants (in all three experiments), Ongoing task stimuli was selected from English lexicon project and Event based prospective memory was main task.	2 (load: low vs. high) x 2 (reminder: reminder vs. no reminder) between subjects design for experiment 1 and for remaining experiments… 2(load: low vs. high, within)X2(reminder: reminder vs. no reminders, between) mixed subjects design was used	Prospective memory can get improved by use of reminders specially when cognitive load is high.
Ball et al. (2022)	Individual differences in working memory capacity predict benefits to memory from intention offloading	260 participants, Delayed intentions task(letters task, numbers task with ascending and descending order), Working memory tasks(reading span, operation span, symmetry span)	3(intention offloading task: letters, numbers ascending, numbers descending)X 3(working memory tasks: reading span, operation span, symmetry span)X3(conditions: forced internal, forced external, choice condition) within participants design was used.	For people with low working memory , use of reminders improved performance for delayed intentions
Brown (2021)	Enhancing short term memory storage through cognitive offloading	57 participants, immediate serial recall task, operation span task, symmetry span task.	2 offloading (option to choose type on computer x no option to type on computer) X5(set size: 2vs 4vs6vs8vs10) within subjects design.	Memory capacity is not responsible for offloading and offloading is useful for higher set sizes.

Other latest work is related with (i) cognitive offloading is useful for older adults (Burnett & Richmond, 2023) (ii) full offloading is more useful than partial offloading (Richmond et al., 2023). Not only this, framing is key to offloading behaviour (Fröscher et al., 2022). Sometimes aging can also be associated with reduced choice for offloading behaviour (Tsai et al., 2022).



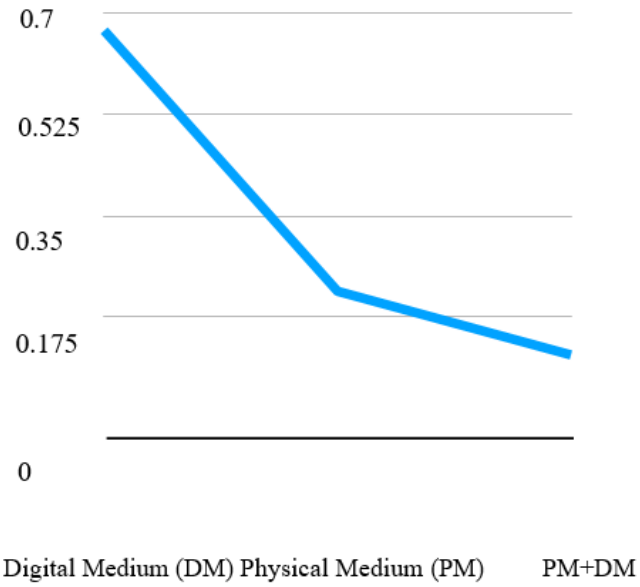


Fig.1 Sample wise studies

Fig.2 Medium wise studies

CONCLUSION AND FUTURE DIRECTIONS

Cognitive offloading has practical relevance in learning, education, memory and problem solving. It has been studied by considering varieties of sample like clinical, children and normal population and Fig (1) is showing the proportion of number of studies.

Medium specific studies have been found in the literature. It has two mediums namely either digital or physical. Participants with digital information loaded rated themselves more knowledgeable comparatively to physical-medium and Fig (2) is showing the proportion of studies medium wise.

Physiological basis of cognitive offloading is a bit less explored area, as limited number of studies has been found. Similarity of cognitive offloading with list method directed forgetting (cue to forget a given list and learning instead a new one) has been found in literature.

It was also found that as cognitive load increases or people with low working memory, in both cases, reminders use (offloading cognition) augments our cognitive capabilities.

Cognitive offloading is well studied in the memory domain. The probable work which can be done: whether can cognitive offloading be related to mood and context dependent memory. Whether cognitive offloading is prevalent on the phonological level, shallow level or semantic level in the levels of processing view. Choice/No-choice paradigm is prevalent to study cognitive offloading, further paradigms specially computer-based laboratory paradigms can be developed using different other non-verbal tasks like pattern copy task, progressive matrices task, corsi block task etc. Whether different psychological states can be correlated with the cognitive offloading by making memory level constant. Cognitive offloading cannot be denied in the present era. It comes with both potential benefits and costs. It can be explored in a way about how to increase its benefits and reduce its cost. So, still much work is yet to be done in cognitive offloading.

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