

Abstraction: An alternative neurocognitive account of recognition, prediction, and decision making

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We commend the authors for a thoughtful and much-needed focus on abstraction, integrating developmental, cognitive, social, and neuroscience literature. This discussion and future work would benefit from drawing on perspectives from software and systems engineering incorporated into recent formalizations of fuzzy-trace theory (Broniatowski & Reyna 2018). Fuzzy-trace theory has spawned an extensive literature that directly relates to *abstraction*, *representational diversity*, *neurocognition*, and *psychopathology* that provides important constraints and alternative evidence-based conceptions of abstraction.

Specifically, the theory distinguishes verbatim representation of information – symbolic representation of concrete, surface form – from gist representation – “fuzzy” bottom-line meaning (Reyna 2012). Gist varies in abstraction of content – called “hierarchy of gist.” In socio-technical systems engineering, Rasmussen (1985) defines two types of hierarchies: abstraction and aggregation. Abstraction pertains to gist in that it emphasizes embedding items within their contexts such that they have a meaningful purpose. Aggregation emphasizes combination of parts into wholes such that “higher” elements in the hierarchy contain “lower” elements, hiding their contents.

We apply both kinds of hierarchies. Implementing fuzzy-trace theory, we define mental representations that vary in abstraction – categorical gist, ordinal gist, and interval verbatim. However, gist-based abstraction is not verbatim-based aggregation, and gist is not derived from verbatim representations. Aggregation rules can take verbatim representations as input, such as combining probabilities and outcomes using *rote* procedures into precise expected values, but this is not abstraction in the gist sense. Our literature review contradicts the assertion that “every action an organism makes is an attempt to reduce uncertainty”; decision makers sometimes seek uncertainty (e.g., for losses), which has profound implications for legal (rejecting plea bargains) and medical decision-making (seeking experimental treatment when terminally ill).

Notably, more abstract levels of the gist hierarchy use a looser, more parsimonious rule (compared to other decision theories) by specifying a partial order in which representations can be, but need not be, ordered. This looser rule reflects fuzzy-trace theory's emphasis on fuzzy processing. Broadly, within each level of representation, different aggregation procedures take the form of different order relations between

elements in each set. Thus, we integrate notions of abstraction found in software engineering and socio-technical systems engineering with fuzzy-trace theory's levels of mental representation.

These theoretical ideas predict numerous results that are directly relevant to the authors' claims. Space limitations permit only a few illustrations. For example, with its roots in psycholinguistics, fuzzy-trace theory absorbed concepts such as scripts/schemas cited by the authors, but modified them to accommodate serious empirical contradictions (e.g., Alba & Hasher 1983). The theory also goes beyond dualisms such as model-free versus model-based or declarative versus procedural memory because data demanded it. The old ideas that "Although episodic memory is more detailed and concrete than semantic memory, it is nonetheless *declarative*; namely, information that can be readily put into words" and "as such may be considered more abstract" have been superseded by evidence showing that episodic memory consists of both verbatim and gist memories. The whole of the false-memory literature speaks against the notion that such memories "can be readily put into words." Moreover, the ability to articulate cognitive processes, such as memory, is a faculty distinct from representational abstraction (as much research showed). In any case, words are not "considered more abstract," but, rather, vary in abstraction. Phenomenology of a false memory (vivid) should not be confused with the abstractness of the representation: "concrete, vivid simulations can easily give rise to false memories." The opposite is true; concreteness and imageability are *negatively* related to false memory, per theory (Brainerd et al. 2008).

Further, prediction does not necessarily entail abstraction (or deliberation). Indeed, current reinforcement and prediction-error paradigms, especially in cognitive neuroscience, emphasize rote memorization. However, in fuzzy-trace theory, there are two main ways people make predictions: through verbatim memory for event frequencies (the number of times an event has happened) or gist-based beliefs about why events occur (Mills et al. 2008). Neurocognitive underpinnings for this fuzzy-trace-theory distinction have been delineated (d'Acremont et al. 2013; see Spreng & Turner 2019, for a theoretically compatible neurocognitive theory that shares the authors' focus on the default-mode network). Thus, rote memory for frequency counts is not abstract, it reflects concrete experience, as does mindless association of events solely through "spatiotemporal contiguity." Although association between events can be abstract in the mind of the theorist, it is not necessarily abstract in the mind of a rat. Any two things that can be related are not necessarily related abstractly.

When abstraction was manipulated per construal level theory, its effect on decision quality was mediated by gist representations (a potential rapprochement; Fukukura et al. 2013). Contrary to other theories, fuzzier, less detailed representations are associated with contextually biased but higher-quality developmentally *advanced* decision-making (Helm

et al. [2018](#); Reyna et al. [2011](#)). Extensive evidence contradicts the assertion that “In order for a target-representation to be functional, it must be accurate *and* detailed. When either condition is not met, the target representation is useless.”

According to fuzzy-trace theory, representational diversity, then, is realized whenever people encode information, but the relative emphasis on different levels of abstraction varies across age and individual differences (Reyna & Brainerd [2011](#)). Among those individual differences, brain and behavioral analyses have linked (lack of) abstract thinking to “psychopathology,” what we describe as atypical information-processing, including autism, adult (as opposed to adolescent) criminality, and psychopathy (Reyna & Panagiotopoulos, [in press](#); Reyna et al. [2018](#)). For example, noncriminal risk-taking behavior was associated with emotional reactivity (amygdala) and reward motivation (striatal) areas, whereas criminal behavior was associated with greater activation in temporal and parietal cortices, their junction, and insula. Neurocognitive and experimental evidence converged on the conclusion that psychopathology was associated with more objective, seemingly rational verbatim processing, rather than developmentally typical reliance on abstract (but contextually biased) gist in adulthood.

In sum, tasks, such as recognition or prospection, are solved differently using concrete verbatim-based processing and abstract gist-based processing. This distinction predicts some effects discussed by the authors and fundamentally contradicts others. Scientific progress can best be achieved by integrating prior evidence with the authors’ exciting ideas about abstraction.

References

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- Alba, J. W. & Hasher, L. (1983) Is memory schematic? *Psychological Bulletin* 93(2):203–231. <https://doi.org/10.1037/0033-2909.93.2.203> (<https://doi.org/10.1037/0033-2909.93.2.203>). [CrossRef \(http://dx.doi.org/10.1037/0033-2909.93.2.203\)](http://dx.doi.org/10.1037/0033-2909.93.2.203) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=Is+memory+schematic?&publication+year=1983&author=Alba+J.+W.&author=Hasher+L&journal=Psychological+Bulletin&volume=93&doi=10.1037/0033-2909.93.2.203&pages=203-231\)](https://scholar.google.com/scholar_lookup?title=Is+memory+schematic?&publication+year=1983&author=Alba+J.+W.&author=Hasher+L&journal=Psychological+Bulletin&volume=93&doi=10.1037/0033-2909.93.2.203&pages=203-231)
-
- Brainerd, C. J., Yang, Y., Reyna, V. F., Howe, M. L. & Mills, B. A. (2008) Semantic processing in “associative” false memory. *Psychonomic Bulletin & Review* 15(6):1035–1053. doi: 10.3758/PBR.15.6.1035. [CrossRef \(http://dx.doi.org/10.3758/PBR.15.6.1035\)](http://dx.doi.org/10.3758/PBR.15.6.1035) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=Semantic+processing+in+%E2%80%9Cassociative%E2%80%9D+false+memory&publication+year=2008&author=Brainerd+1053\)](https://scholar.google.com/scholar_lookup?title=Semantic+processing+in+%E2%80%9Cassociative%E2%80%9D+false+memory&publication+year=2008&author=Brainerd+1053) | [PubMed \(https://www.ncbi.nlm.nih.gov/pubmed/19001566\)](https://www.ncbi.nlm.nih.gov/pubmed/19001566)
-
- Broniatowski, D. A. & Reyna, V. F. (2018) A formal model of fuzzy-trace theory: Variations on framing effects and the Allais Paradox. *Decision* 5(4):205–52. <https://doi.org/10.1037/dec0000083> (<https://doi.org/10.1037/dec0000083>). [CrossRef \(http://dx.doi.org/10.1037/dec0000083\)](http://dx.doi.org/10.1037/dec0000083) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=A+formal+model+of+fuzzy-trace+theory:+Variations+on+framing+effects+and+the+Allais+Paradox&publication+year=2018&author=Broniatowski+D.+A.&](https://scholar.google.com/scholar_lookup?title=A+formal+model+of+fuzzy-trace+theory:+Variations+on+framing+effects+and+the+Allais+Paradox&publication+year=2018&author=Broniatowski+D.+A.&) | [PubMed \(https://www.ncbi.nlm.nih.gov/pubmed/30320145\)](https://www.ncbi.nlm.nih.gov/pubmed/30320145)
-
- d'Acromont, M., Fornari, E. & Bossaerts, P. (2013) Activity in inferior parietal and medial prefrontal cortex signals the accumulation of evidence in a probability learning task. *PLOS Computational Biology* 9:e1002895. doi: 10.1371/journal.pcbi.1002895. [CrossRef \(http://dx.doi.org/10.1371/journal.pcbi.1002895\)](http://dx.doi.org/10.1371/journal.pcbi.1002895) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=Activity+in+inferior+parietal+and+medial+prefrontal+cortex+signals+the+accumulation+of+evidence+in+a+probability+le](https://scholar.google.com/scholar_lookup?title=Activity+in+inferior+parietal+and+medial+prefrontal+cortex+signals+the+accumulation+of+evidence+in+a+probability+le)
-
- Fukukura, J., Ferguson, M. J. & Fujita, K. (2013) Psychological distance can improve decision making under information overload via gist memory. *Journal of Experimental Psychology: General* 142(3):658–65. doi: 10.1037/a0030730. [CrossRef \(http://dx.doi.org/10.1037/a0030730\)](http://dx.doi.org/10.1037/a0030730) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=Psychological+distance+can+improve+decision+making+under+information+overload+via+gist+memory&publication+ye](https://scholar.google.com/scholar_lookup?title=Psychological+distance+can+improve+decision+making+under+information+overload+via+gist+memory&publication+ye) | [PubMed \(https://www.ncbi.nlm.nih.gov/pubmed/23106304\)](https://www.ncbi.nlm.nih.gov/pubmed/23106304)
-
- Helm, R. K., Reyna, V. F., Franz, A. A. & Novick, R. Z. (2018) Too young to plead? Risk, rationality, and plea bargaining's innocence problem in adolescents. *Psychology, Public Policy, and Law* 24(2):180–91. doi: 10.1037/law0000156. [CrossRef \(http://dx.doi.org/10.1037/law0000156\)](http://dx.doi.org/10.1037/law0000156) | [Google Scholar \(https://scholar.google.com/scholar_lookup?title=Too+young+to+plead?+Risk+rationality+and+plea+bargaining's+innocence+problem+in+adolescents.+Psychology&publication+year=2018&author=H](https://scholar.google.com/scholar_lookup?title=Too+young+to+plead?+Risk+rationality+and+plea+bargaining's+innocence+problem+in+adolescents.+Psychology&publication+year=2018&author=H)
-
- Mills, B. A., Reyna, V. F. & Estrada, S. (2008) Explaining contradictory relations between risk perception and risk taking. *Psychological Science* 19(5):429–34. doi: 10.1111/j.1467-9280.2008.02104.x.

CrossRef (<http://dx.doi.org/10.1111/j.1467-9280.2008.02104.x>) |
Google Scholar (https://scholar.google.com/scholar_lookup?title=Explaining+contradictory+relations+between+risk+perception+and+risk+taking+publication+year=2008&author=Mills+B.+9280.2008.02104.x)
| PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/18466401>)

Rasmussen, J. (1985) The role of hierarchical knowledge representation in decision making and system management. *IEEE Transactions on Systems, Man, and Cybernetics* 15(2):234–43.
CrossRef (<http://dx.doi.org/10.1109/TSMC.1985.6313353>) |
Google Scholar (https://scholar.google.com/scholar_lookup?title=The+role+of+hierarchical+knowledge+representation+in+decision+making+and+system+management.+IEEE+Transaction)

Reyna, V. F. (2012) A new intuitionism: Meaning, memory, and development in fuzzy-trace theory. *Judgment and Decision Making* 7(3):332–59.
Google Scholar (https://scholar.google.com/scholar_lookup?title=A+new+intuitionism:+Meaning+memory+and+development+in+fuzzy-trace+theory&publication+year=2012&author=Reyna+V.+F&journal=Judgment+and+Decision+Making&volume=7)
| PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/25530822>)

Reyna, V. F. & Brainerd, C. J. (2011) Dual processes in decision making and developmental neuroscience: A fuzzy-trace model. *Developmental Review* 31:180–206.
Google Scholar (https://scholar.google.com/scholar_lookup?title=Dual+processes+in+decision+making+and+developmental+neuroscience:+A+fuzzy-trace+model&publication+year=2011&author=Reyna+V.+F.&author=Brainerd+C.+J&journal=Developmental+Review&volume=3206)
| PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/22096268>)

Reyna, V. F., Estrada, S. M., DeMarinis, J. A., Myers, R. M., Stanis, J. M. & Mills, B. A. (2011) Neurobiological and memory models of risky decision making in adolescents versus young adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 37(5):1125–42. CrossRef (<http://dx.doi.org/10.1037/a0023943>) |
Google Scholar (https://scholar.google.com/scholar_lookup?title=Neurobiological+and+memory+models+of+risky+decision+making+in+adolescents+versus+young+adults.+Journal+of+Ex)

Reyna, V. F., Helm, R. K., Weldon, R. B., Shah, P. D., Turpin, A. G. & Govindgari, S. (2018) Brain activation covaries with reported criminal behaviors when making risky choices: A fuzzy-trace theory approach. *Journal of Experimental Psychology: General* 147(7):1094–1109. CrossRef (<http://dx.doi.org/10.1037/xge0000434>) |
Google Scholar (https://scholar.google.com/scholar_lookup?title=Brain+activation+covaries+with+reported+criminal+behavior+trace+theory+approach&publication+year=2018&author=Reyna+V.+F.&author=Helm+R.+K.&author=Weldon+R.+B.&author=Sh 1109)
| PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/29975093>)

Reyna, V. F. & Panagiotopoulos, C. (in press) Morals, money, and risk taking from childhood to adulthood: The neurodevelopmental framework of fuzzy-trace theory. In: *The social brain – a developmental perspective*, ed. Decety, J.. The MIT Press.
Google Scholar (https://scholar.google.com/scholar_lookup?title=The+social+brain+%E2%80%93+a+developmental+perspective&publication+year=in+press&author=Reyna+V.+F.&author=)

Spreng, R. N. & Turner, G. R. (2019) The shifting architecture of cognition and brain function in older adulthood. *Perspectives on Psychological Science* 14(4):523–42.

CrossRef (<http://dx.doi.org/10.1177/1745691619827511>) |

Google Scholar (https://scholar.google.com/scholar_lookup?

[title=The+shifting+architecture+of+cognition+and+brain+function+in+older+adulthood&publication+year=2019&author=Spren](https://scholar.google.com/scholar_lookup?title=The+shifting+architecture+of+cognition+and+brain+function+in+older+adulthood&publication+year=2019&author=Spren)

| PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/31013206>)