Operationalization of planning based on Tower Tasks (TT) applied to clinical population – a meta-analysis.

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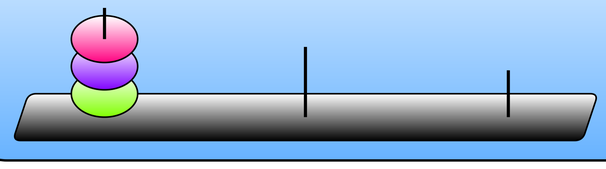
Introduction

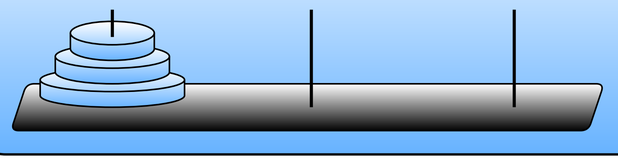
- **Tower Tasks (TT)** are used for testing planning, recursive problem solving, and counterfactual thinking in clinical population (Henke, 2010).
- However, TT has been criticised as unreliable given the plurality of variants (Goel, 1995; Goel and Grafman, 1995; 2000), and plurality of solving stragegies (Andrews et al., 2014; Sulivan et al., 2009).
- The analysed studies (in cells below) use different versions of TT (on the right, and respective columns of the table), often without recogniton of different solving strategies.
- Nonetheless, the studies claim to test "planning" abilities in patients.
- Plurality of variants, solving strategies, and methods of measuring performance constitute severe challenges when comparing the studies

3-balls/3-pockets



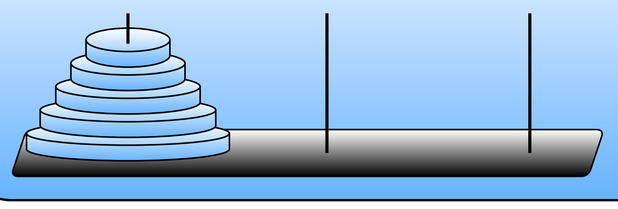
- Simplified problem without size constraint developed by Shalice (1982).
- Known as Tower of London, inaccurately implemented as a proxy of planning skills.

3-discs



- Also known in the literature as Tower of London.
- Rarely used in the available literature.

4-discs/5-discs



- Known also as Tower of Hanoi (5-discs) and Tower of Toronto (4-discs).
- Originally implemented in clinical psychology tests by Cohen et al., 1985).

VERSIONS OF THE TT

	3-balls/3-pockets	3-discs	4-discs	5-discs
Fronto-Temporal Damage	**Frontal Damage**	**IMPAIRED** n=26/c=26 (Owen et al., 1990)**	**NORMAL** n=13/c=13(Anders and Van der Linden, 2001)	**UNKNOWN** n=21/c=44! (Morris et al., 1997)	**IMPAIRED** n=14/c=40 (Andrews et al., 2014)	**IMPAIRED** n=20/c=20 (Goel and Grafman, 1995)***
		IMPAIRED n=14/c=15 (Carlin et al., 2000)**				
	Mixed Frontal Damage			**NORMAL** n=2/c=24! (Saint-Cyr et al., 1988)*	**IMPAIRED** n=2/c=24! (Saint-Cyr et al., 1988)*	**NORMAL** n=12/c=20 (Cohen et al., 1985)*
				NORMAL n=41/c=49 (Gloser and Doodglass, 1990)	**UNKNOWN** n=20/c=40 (Schmidtke et al., 1996)	**IMPAIRED** n=2/c=0 (Xu and Corkin, 2001)***
				IMPAIRED n24/c=37 (Leon-Carrion et al., 1991)		
	Korsakoff Syndrome					**IMPAIRED** n=6/c=12! (Butters et al., 1985)
	Frontotemporal Dementia Atrophy	**IMPAIRED** n=15/c=15 (Carlin et al., 2000)**	**UNKNOWN** n=94/c=0 (Franceschi et al., 2011)			**IMPAIRED** n=44/c=27! (FTD) (Carey et al., 2008)
	Temporal damage	**NORMAL** n=16/c=32! (Baumard et al., 2018)		**UNKNOWN** n=38/c=44! (Morris et al., 1997)		
	Mild Cognitive Impairements MMSE>20	**IMPAIRED** n=60/c=60! (de Paula et al., 2013)***	**IMPAIRED** n=161/c=212 (Franceschi et al., 2007)***	**IMPAIRED** n=30/c=40 (Marchegiani et al., 2010)		**IMPAIRED** n=30/c=27! (Carey et al., 2008)
		NORMAL n=40/c=22! (Cammisuli and Sportiello, 2017)	**UNKNOWN** n=42/c=0 (de Paula and Malloy-Diniz, 2013)	**IMPAIRED** n=31/c=31 (Huang et al., 2017)		
		NORMAL n=51/c=42! (Rainville et al., 2012)***	**NORMAL** n=30/c=42! (Rainville et al., 2012)***			
		IMPAIRED n=15/c=17 (Rainville et al., 2002)	**IMPAIRED** n=32/c=32! (Baumard et al., 2018)	**IMPAIRED** n=17/c=17 (Coubard et al., 2011)		
	Dementia Alzheimer Type MMSE <20	**IMPAIRED** n=60/c=60! (de Paula et al., 2012)***	**UNKNOWN** n=160/c=0 (Franceschi et al., 2011)		**UNKNOWN** n=24/c=215! (Balachandar et al., 2015)	**UNKNOWN** n=24/c=215! (Balachandar et al., 2015)	**IMPAIRED** n=24/c=215! (Balachandar et al., 2015)
		UNKNOWN n=13/c=222 (Lange et al., 1995)	**IMPAIRED** n=76/c=0 (de Paula and Malloy-Diniz, 2013)		**UNKNOWN** n=79/c=0 (Ben Ayed et al., 2021)	**NORMAL** n=18/c=18 (Beaunieux et al., 2012)	
		IMPAIRED n=21/c=33 (Satler et al., 2017)	**UNKNOWN** n=29/c=0 (Woo et al., 2010)				
	Other Front-Temporal Damage	**IMPAIRED** n=9/c=32! (Baumard et al., 2018)					
Basal Ganglia / Cerebellar degeneration	**Parkinson's Disease (early) H&Y < 2.5**	**NORMAL** n=15/c=15 (Owen et al., 1992)	**NORMAL** n=15/c=15 (Owen et al., 1992)		**NORMAL** n=24/c=24! (Saint-Cyr et al., 1988)*	**IMPAIRED** n=24/c=24! (Saint-Cyr et al., 1988)*	
		NORMAL n=6/c=6 (Dagher et al., 2001)	**NORMAL** n=12/c=12 (Beauchamp et al., 2008b)		**NORMAL** n=12/c=18 (Morris et al., 1988)	**IMPAIRED** n=9/c=12! (Daum et al., 1995)	
	Parkinson's Disease (advanced) H&Y > 2.5	**IMPAIRED** n=12/c=12 (Beauchamp et al., 2008b)	**IMPAIRED** n=24/c=22 (Beauchamp et al., 2008b)	**IMPAIRED** n=65/c=34 (Culberstone et al., 2004)			
		NORMAL n=24/c=24 (Robbins et al., 1994)	**IMPAIRED** n=14/c=14 (Owen et al., 1992)				
	Parkinson's Disease and MCI	**NORMAL** n=40/c=22! (Cammisuli and Sportiello, 2017)	**IMPAIRED** n=18/c=18 (Robbins et al., 1994)			**IMPAIRED** n=14/c=12! (Daum et al., 1995)	
	Multiple System Atrophy (MSA)	**NORMAL** n=16/c=16 (Robbins et al., 1994)	**NORMAL** n=16/c=16 (Robbins et al., 1992)				
	Huntington's Disease (early)	**IMPAIRED** n=20/c=20 (Watkins et al., 2000)			**NORMAL** n=4/c=24! (Saint-Cyr et al., 1988)*	**NORMAL** n=4/c=24! (Saint-Cyr et al., 1988)*	**NORMAL** n=6/c=12! (Butters et al., 1985)
					IMPAIRED n=4/c=24! (Saint-Cyr et al., 1988)*	**MIXED** n=4/c=24! (Saint-Cyr et al., 1988)*	
	Huntington's Disease (mixed)	**IMPAIRED** n=10/c=55 (Lange et al., 1995)					
	Huntington's Disease (late)				**IMPAIRED** n=4/c=24! (Saint-Cyr et al., 1988)*	**IMPAIRED** n=4/c=24! (Saint-Cyr et al., 1988)*	**IMPAIRED** n=9/c=12! (Butters et al., 1985)
	Pure cerebellar degeneration (e.g. CCA)					**NORMAL** n=13/c=13! (Ackerman et al., 1993)	**IMPAIRED** n=9/c=12 (Grafman et al., 1992)
	Cerebellum and brainestem degeneration (e.g. OPCA)					**NORMAL** n=6/c=13! (Ackerman et al., 1993)	

Key insigths

- Simplified TT problems are criticised as too different from original 4-discs/5-discs problems as they do not require planning or recursion (Goel and Grafman, 2000).
- Both clinical and control samples have been shown to implement perceptual strategies (Goel and Grafman, 1995).

Conclusion

- Operationalization of planning should involve contemporary research such as reinforcement learning models of designing action policy based on an inferred structure of surroundings.
- The operationalization has to recognise cooperation and competition to planning processes in order to take into account plurality of solving strategies.
- Based on such careful operationalization of planning, a new planning task should be designed and validated.