11th UK Annual Rasch User Group Meeting

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Human Factors Measurement in Gaming for Rehabilitation Robotics

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Structure

1. Introduction – what are the issues?
2. Human factors, gaming design and Rasch
3. Objectives
4. Pac-Man experiment – design
5. Pac-Man experiment - result
6. Proposed next steps

Introduction – stroke and rehabilitation

Source: Sivan, M. et al., 2014. Home-based Computer Assisted Arm Rehabilitation (hCAAR) robotic device for upper limb exercises after stroke: results of a feasibility study in home setting. *Journal of NeuroEngineering and Rehabilitation*, 11(1), p.163. Available at: http://www.jneuroengrehab.com/content/11/1/163.

- Cost of stroke care is £9 billion a year – 5% NHS cost
- Stroke may affect upper limb function, which has a high level of movement complexity
- Hence, improving upper limb function has been the main majority of investigation in this field
- Numerous advantages of robotic technology in rehabilitation:
  1. Repetitive meaningful tasks
  2. Greater intensity of practice
  3. Stimulating and engaging environment for user
  4. Alleviate the labour-intensive aspects of hands-on conventional therapy

Introduction – Rasch in rehabilitation

Source: Luigi, T., 2003. Measuring Behaviours and Perceptions: Rash Analysis As a Tool for Rehabilitation Research. *J Rehabilitation Medicine*, 35, pp.105–115.

- Developed by Georg Rasch, a Danish mathematician, in 1960
- Statistical model, allowing the use of cumulative raw scores to form a linear continuous measures (interval measures) for ability (for subjects) and difficulty (for items)
- An illustration…..

If -
D = difference in difficulty/distance
X = standing
Y = walking
Z = climbing upstairs
A = ability of person 1
B = ability of person 2

Then -
D(Z-Y) = 4D(Y-X)
D(Z-Y) = D1
D(Y-X) = D2
D1 = 4D2
F(A|D1) = 4F(A|D2)
F(B|D1) = 4F(B|D2)

Human factors, gaming design, and Rasch

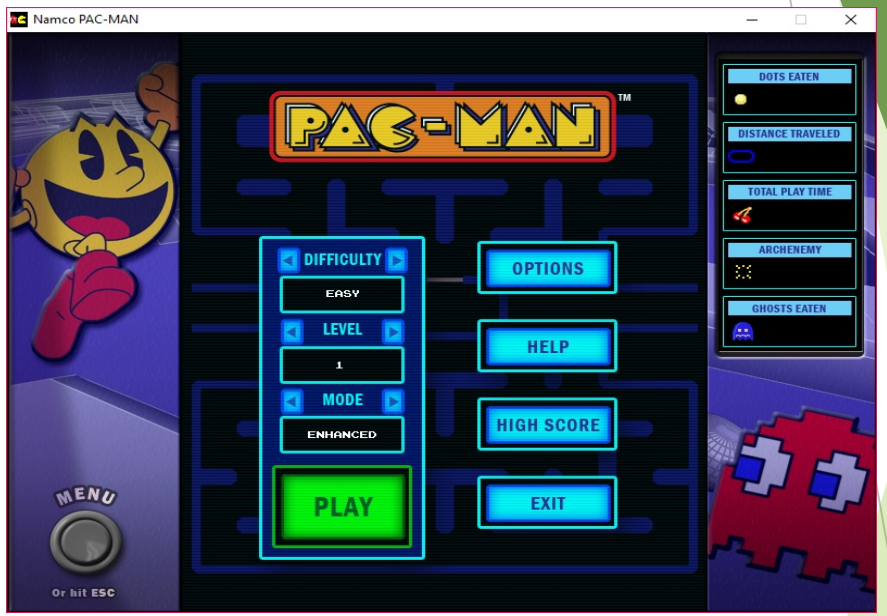
- How to improve the effectiveness of rehabilitation robotics for physiotherapy?
- How to improve the link between patient's ability and difficulty level of task?
- How to improve the game design used in the physiotherapy?
- How to measure difficulty levels of task in the game?

Human factors, gaming design, and Rasch

1. To identify an existing game and explore its tasks and observed human factors
2. To measure the difficulty of gaming tasks and ability of players using the Rasch model
3. To obtain evidence of an application of Rasch model as a quantitative measure construct methodology in human factors measurement in game design

Pac-Man Experiment – Design (1)

- 148 respondents in the University of Leeds' area, recruited randomly
- 72% are male and 28% are female
- The age groups of the participants are as follows.
  1. 15 years old or less -
  2. 16 – 25 years old 73%
  3. 26 – 35 years old 17%
  4. 36 – 45 years old 8%
  5. 46 years old or more 2%
- Each respondent was given a trial session, followed by a recorded session; each session consisted of "one game" or five lives



Pac-Man Experiment – Design (2)
person factors and their categories

	Person Factors	1	2	3	4	5
1	Gender	Male	Female			
2	Age	less than 15 years old	16-25 years old	26-35 years old	36-45 years old	more than 45 years old
3	Gaming Experience (hours played/week)	less than 5 hours	6-10 hours	11-20 hours	21-30 hours	more than 30 hours
4	Pac-man Familiarisation	Yes	No			

Pac-Man Experiment – Design (3)
items and their categories

		Difficulty levels/Categories				
Tasks/Items		0	1	2	3	4
1	Eating dots on board 1	no dot	1-60 dots	61-120 dots	121-180 dots	181-240 dots
2	Distance travelled to complete board 1	0-366m	more than 366m			
3	Total play time on board 1	0-60 seconds	more than 60 seconds			
4	Eating energizers on board 1	no energizer	1 energizer	2 energizers	3 energizers	4 energizers
5	Eating monsters on board 1 (maximum number per eaten energizers)	no monster	1 monster	2 monsters	3 monsters	4 monsters
6	Eating fruits on board 1	no fruit	1 fruit	2 fruits		
7	Retain life to complete board 1 (reversal item)	more than 1 life used	1 life used			

Pac-Man Experiment – Design (4)
items and their categories

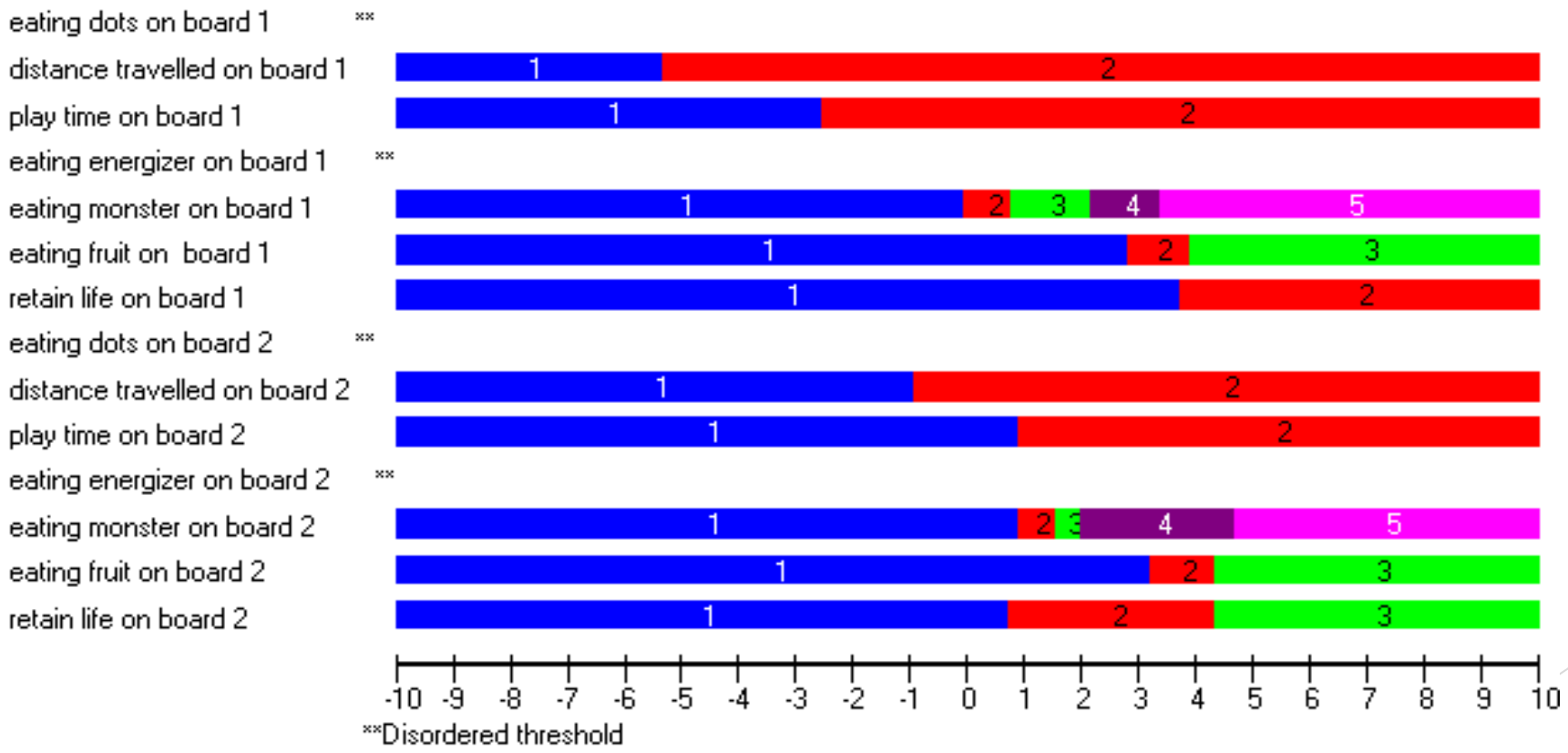
		Difficulty levels/Categories				
Tasks/Items		0	1	2	3	4
8	Eating dots on board 2	no dot	1-60 dots	61-120 dots	121-180 dots	181-240 dots
9	Distance travelled to complete board 2	0-366m	more than 366m			
10	Total play time on board 2	0-60 seconds	more than 60 seconds			
11	Eating energizers on board 2	no energizer	1 energizer	2 energizers	3 energizers	4 energizers
12	Eating monsters on board 2 (maximum number per eaten energizers)	no monster	1 monster	2 monsters	3 monsters	4 monsters
13	Eating fruits on board 2	no fruit	1 fruit	2 fruits		
14	Retain life to complete board 2 *(reversal item)*	not reach board 2	more than 1 life used	1 life used		

Pac-Man Experiment – Result (Initial)

- Chi Square Probability = 0.000000
- Bonferroni adjusted alpha value of $p \leq 0.003571$, (0.05/14), the value indicates some degree of misfit between the model and the data
- Person fit test:
  fit residual mean = -0.2147
  standard deviation = 0.3439
- Person Separation Index (PSI) = 0.86839
- Item fit test:
  fit residual mean = -0.8640
  standard deviation = 2.0627

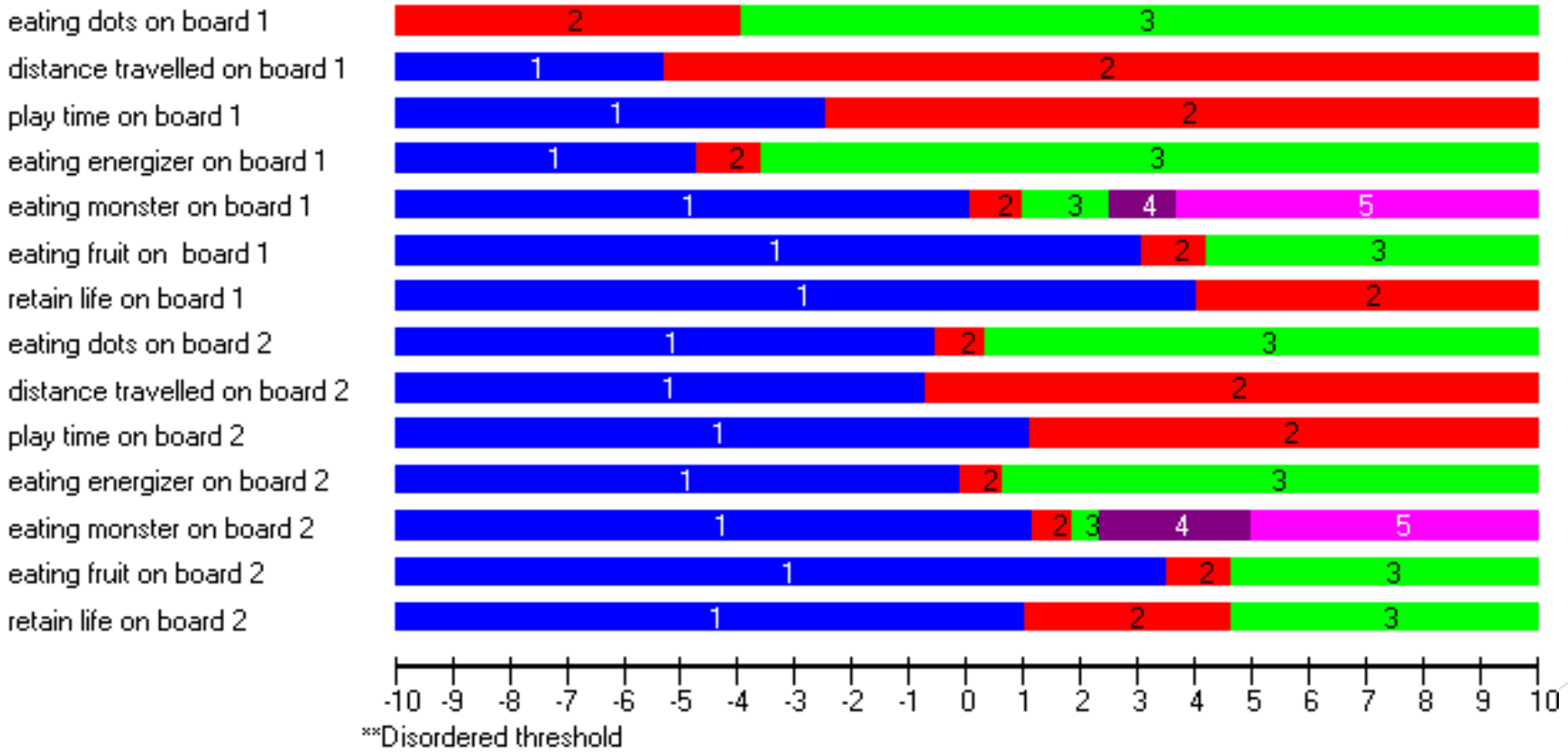
Pac-Man Experiment – Result (2)

RUMM2030 – Threshold Map (Initial Analysis):



Pac-Man Experiment – Result (3)

RUMM2030 – Threshold Map (Ordered):



Pac-Man Experiment – Result (4)

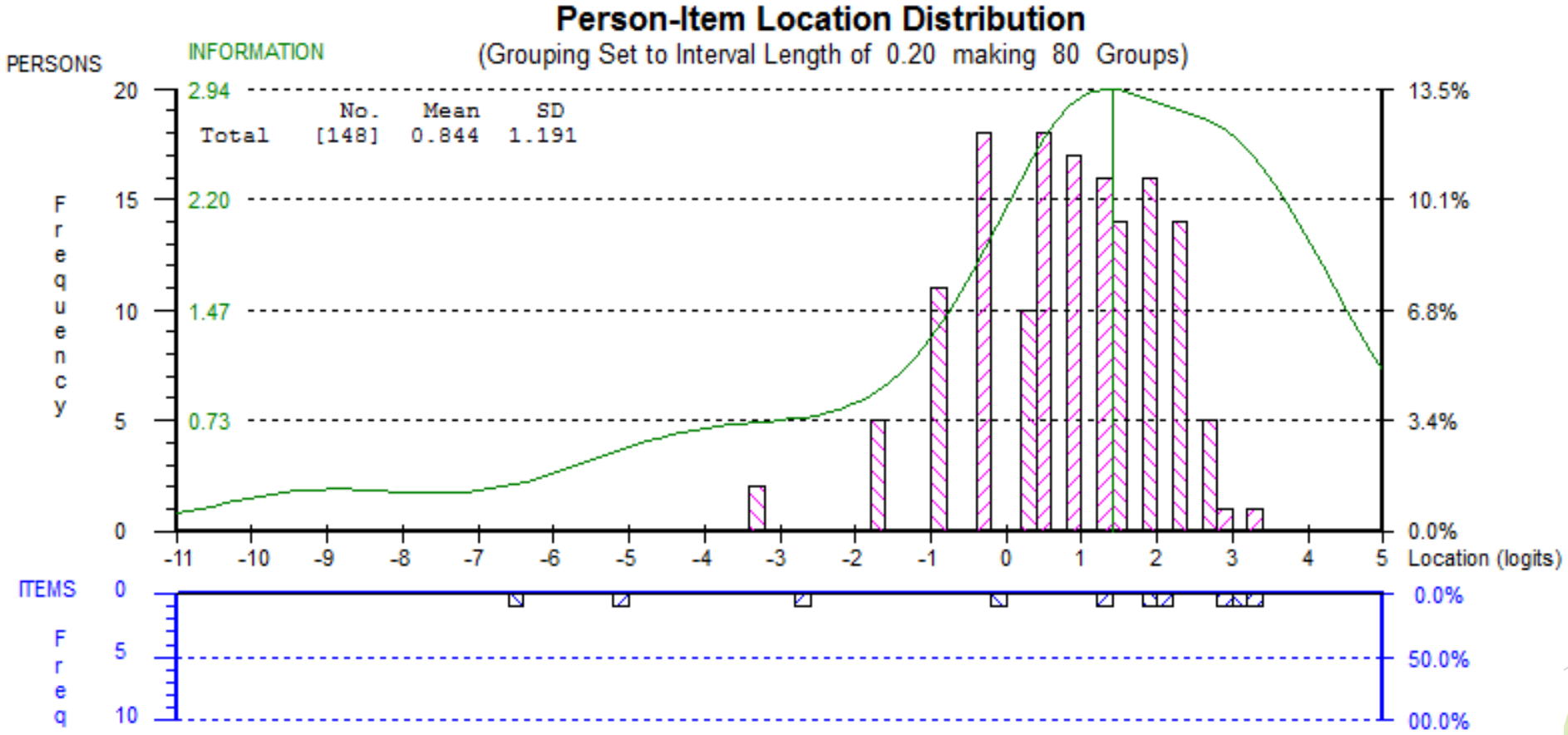
DIFF Summary (1st iteration cut-off value of 0.16):

Item	1	2	3	4	5	6	7	8	9	10	11	12	13
2	-0.19												
3	-0.10	0.01											
4	0.50	-0.22	-0.11										
5	-0.02	-0.12	0.20	-0.06									
6	-0.36	0.06	0.11	-0.17	-0.01								
7	-0.01	0.00	-0.24	-0.01	-0.13	-0.02							
8	-0.06	0.02	-0.16	-0.03	-0.55	-0.22	0.10						
9	-0.09	0.02	-0.14	-0.06	-0.65	-0.23	0.04	0.44					
10	-0.05	0.00	-0.16	-0.04	-0.33	-0.14	0.16	0.55	0.28				
11	-0.07	0.01	-0.18	-0.05	-0.50	-0.20	0.04	0.65	0.50	0.50			
12	-0.03	0.00	-0.09	-0.03	-0.15	-0.17	-0.17	-0.14	0.22	-0.23	-0.10		
13	0.01	0.01	-0.21	0.01	-0.22	0.03	-0.15	-0.03	0.09	-0.09	-0.02	-0.12	
14	0.01	0.02	-0.02	0.03	-0.24	-0.09	0.02	-0.01	0.05	-0.17	-0.10	-0.21	-0.02

Pac-Man Experiment – Result (Final)

- No un-fit person identified
- Item fit test, leaving item 12 – eating monsters on board 2 as an un-fit item with residual value of -3.561.
- Local dependencies (updated cut-off value = 0.12):
  - Item 3 – play time on board 1, with Item 5 – eating monsters on board 1; probability value = 0.15
  - Item 7 – retain life to complete board 1, with item 8 – eating dots on board 2; probability value = 0.15
- Item 3 and 7 continue showing uniform DIF within "game experience" person factor groups
- Unidimensionality of the measure showed no change lower 95% CI-Proportion value of 0.032, which is lower than 0.05 (acceptable)
- Person Separation Index shows a value of 0.687 - the scale does not provide sufficient reliability as a single person measurement

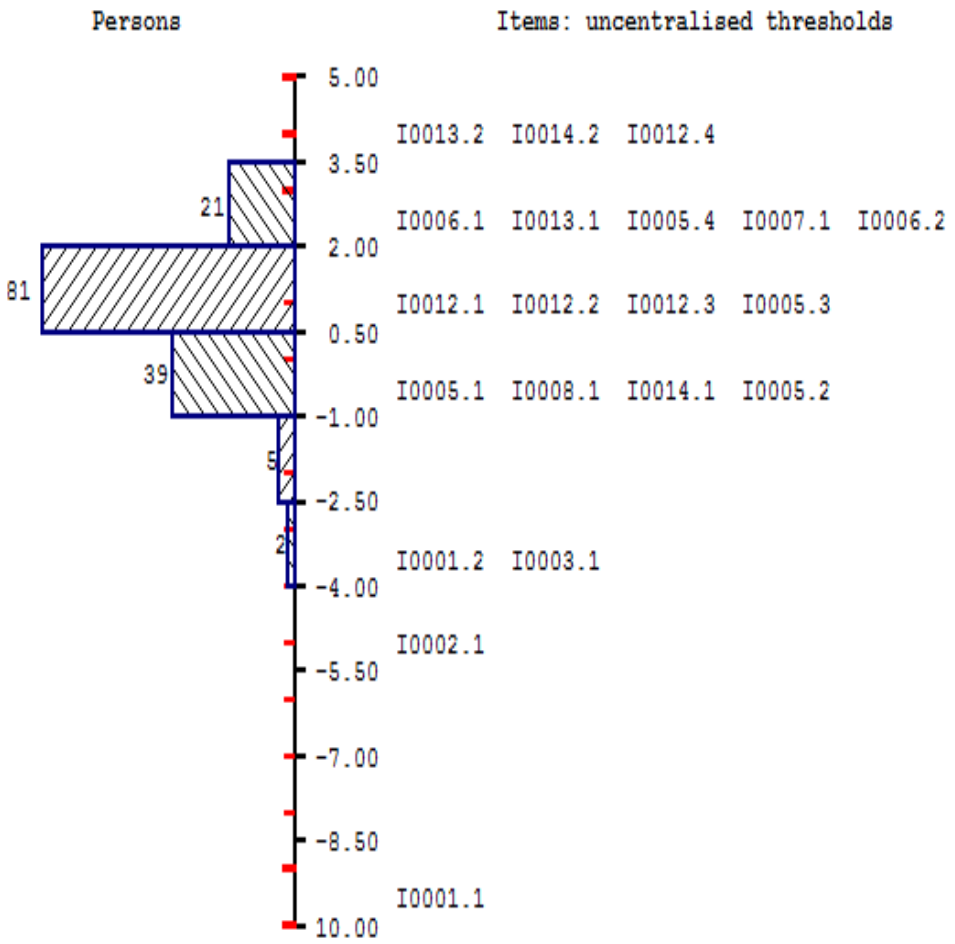
Pac-Man Experiment – Result (Final)

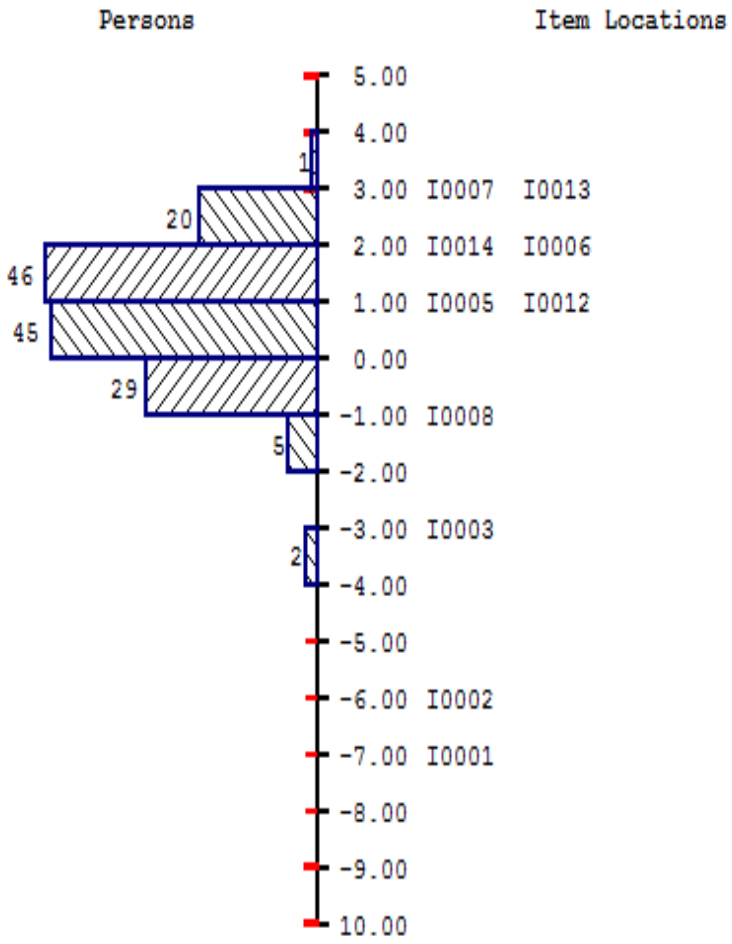


Pac-Man Experiment – Result (Final)

Item	Description	Max Score	Rescored	1	2	3	4	5
I0001	Eating dots on board 1	2	Y	0	1	1	1	2
I0002	Distance travelled on board 1	1		0	1			
I0003	Play time on board 1	1		0	1			
I0005	Eating monsters on board 1	4		0	1	2	3	4
I0006	Eating fruits on board 1	2		0	1	2		
I0007	Retain life to complete board 1	1		0	1			
I0008	Eating dots on board 2	1	Y	0	0	0	0	1
I0012	Eating monsters on board 2	4		0	1	2	3	4
I0013	Eating fruits on board 2	2		0	1	2		
I0014	Retain life to complete board 2	2		0	1	2		

Pac-Man Experiment – Result (Final)





Proposed next steps

- Investigation into games in rehabilitation; using Rasch model in design and development phase
- Investigation into implementing Computer Adaptive Testing to improve the effectiveness of using games in rehabilitation

Any question?

Thank you

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