A Framework for Estimating Difficulty, User Cost and Exclusion from Everyday Tasks

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SUMMARY

Inclusive design research and practice seeks to make everyday tasks more accessible for everyone. Identifying Performance Shaping Factors and assessing their impact on performance is central to estimating difficulty, user cost and potential exclusion from everyday tasks. This paper provides an exploratory Hand Action Framework for examining the extent to which task demands, age and capability Performance Shaping Factors impact performance achieved, difficulty, user cost and task exclusion experienced. A study involving a sample of sixty participants undertaking a range of everyday tasks is provided. The results demonstrate the Hand Action Framework captured a range of hand actions used with Performance Shaping Factors of task demands, age, and capability having a significant impact on hand actions used, performance achieved and user cost experienced.

KEYWORDS

Inclusive Design, Ageing, Ergonomics

Introduction

Societies in England, United Kingdom (ONS, 2023) and globally (UN, 2015) are ageing. Increasing age is associated with increasing levels of disability with approximately 23% of working age people in the United Kingdom having some form of disability increasing to 45% of people over 66 years of age, and 58% of people aged 80 years and over (DWP, 2023).

Increasing age is also associated with decreases in some physical and cognitive capabilities such as mobility, dexterity, memory and vision (Kirk-Wade, 2023) together with increased difficulty performing everyday activities (Yoxall, Langley, Janson, Lewis, Wearn, Hayes & Bix, 2010). It has been estimated, approximately 45% of older adults aged over 60 years of age have reported difficulty performing everyday activities (UN, 2015).

A challenge for inclusive design in the context of ageing impacts on performance of everyday tasks is to firstly recognise relevant capability changes in the ageing population and use this as an input to inform a human centred inclusive design process and outcome. This inclusive design philosophy can result in products that minimise exclusion of less capable users (Clarkson & Keates, 2003).

Using this inclusive design approach requires an understanding of functional capabilities of users relative to their task demands, because exclusion can occur when task demands exceed a person’s capability to effectively respond to them as noted in Figure 1.

Challenges for a unidimensional approach of the type noted above is “*capability*” may not be a unidimensional scale because it can consist of different physical capabilities such as physical strength and manual dexterity (Schmidle, Gulde, Herdegen, Böhme, & Hermsdörfer, 2022) and a range of cognitive capabilities such as perception and memory (Murman, 2015). It appears the extent to which age and capability impacts performance is quite varied depending on the extent of ageing, types of capabilities being measured and context of use for tasks of everyday living (Shin & Kim, 2022).

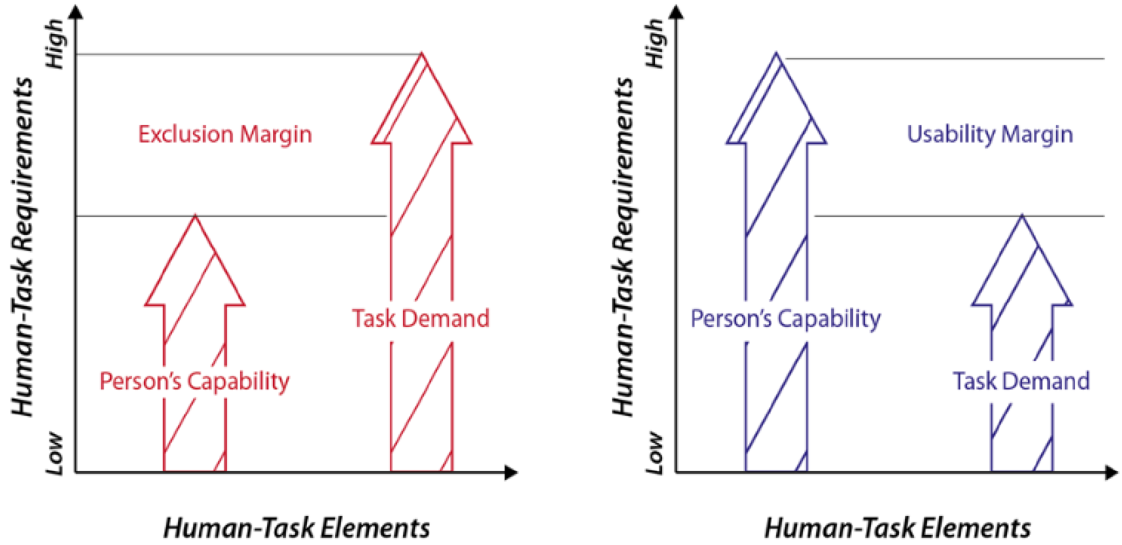

Figure 1: A conceptual representation where task demands exceed users' capabilities (top left: Exclusion) and where human capability exceeds task demands (top right: Usability Margin).

Our hands are central to our interaction with people, space, and products around us and the fine bony architecture of the hands enables an eclectic range of hand actions and capabilities. Identifying Performance Shaping Factors and assessing their impact on hand action performance is central to estimating difficulty and potential exclusion from everyday tasks. The analysis of human characteristics in this context is challenging because much of the existing capability data is fragmented and limited regarding how it can be validly used to predict exclusion.

The current research presents an exploratory framework for examining the extent to which task demands, age and capability Performance Shaping Factors impact hand-based performance and difficulty undertaking everyday tasks.

Much of the hand-based capability data captures either the strength (Dodds, Syddall, Cooper & Sayer, 2014) or dexterity (Agnew, Bolla-Wilson, Kawas & Bleecker, 1988; Desrosiers, Hébert, Bravo & Dutil, 1995) capability, but much of the hand's functional capability to perform everyday tasks involves the integration of both strength and dexterity. Consequently, an initial study involved developing a Hand Action Framework to categorise hand actions used and explain performance using a proposed "*strength x dexterity*" capability approach.

The proposed Hand Action Framework captured the frequency of different hand actions used like other hand taxonomies (e.g. Feix, Romero, Schmiedmayer, Dollar & Kragic, 2015), but this Hand Action Framework was coupled to a systematic examination of task demands, age and capability Performance Shaping Factors which enabled an assessment of performance achieved and potential exclusion from everyday tasks (Nery, Langdon & Clarkson, 2010).

The analysis of the Hand Action Framework was extended in the current research by exploring additional dimension of "*user cost"* which has been decomposed into measures of "*task difficulty*" and "*task exertion*" to provide insight into task demand impacts on overall performance achieved and people's perception of difficulties they experience completing everyday tasks. Furthermore, this research included a more granulated analysis of older age participants so the impact of the "Age" Performance Shaping Factors on performance achieved, difficulty experienced and potential exclusion from everyday tasks could be examined with more resolution (Figure 2).

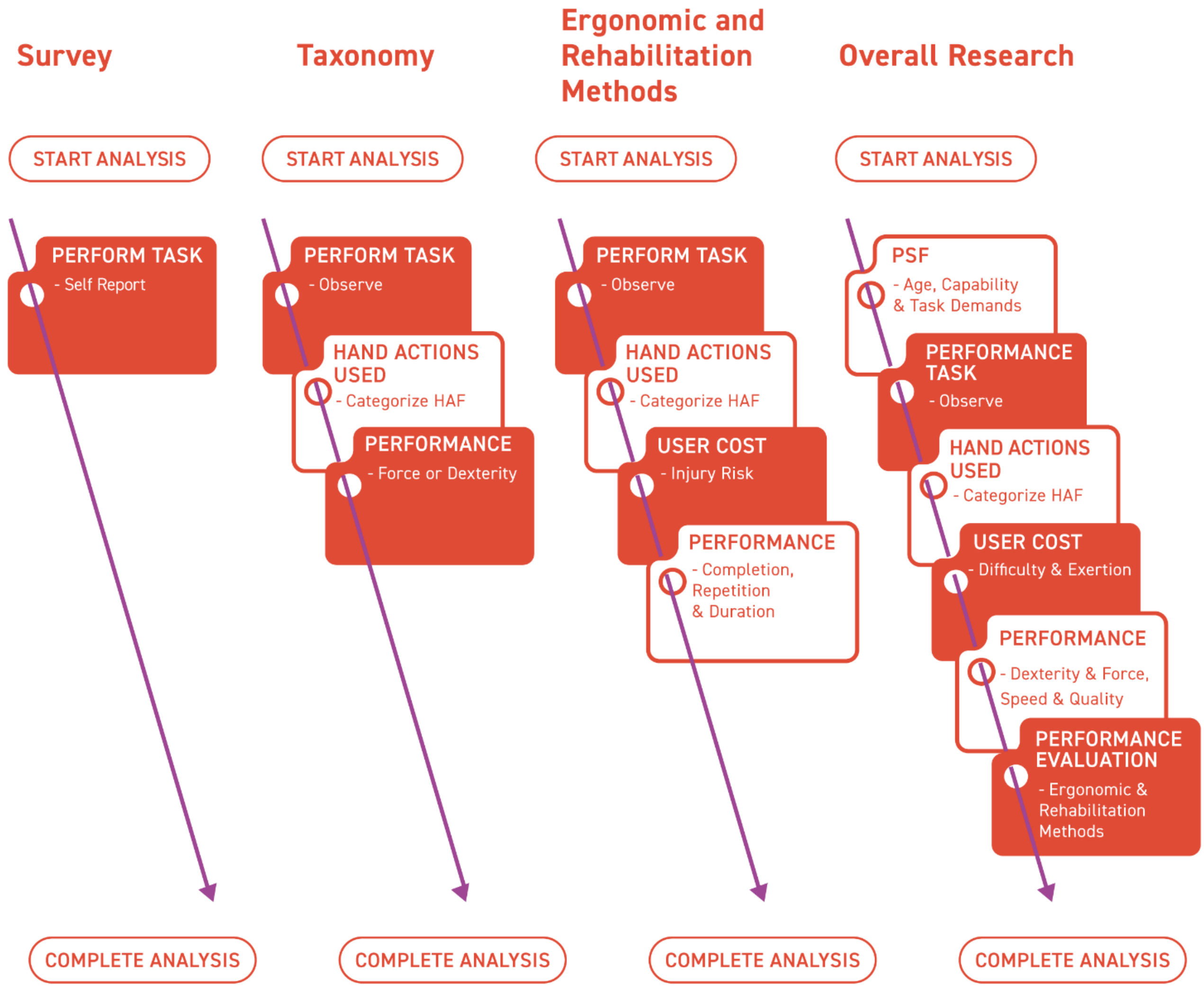

Figure 2: Layers of analysis for survey, taxonomy, ergonomic/rehabilitation methods and the current research

Methodology

Research Design: Table 1 provides an overview of the age ranges and numbers of participants in each study together with capability, user cost methods used in this research.

Capability Measures: Hand grip strength and dexterity measured using Jamar Power Grip Strength Test and Purdue Pegboard Test respectively. All individual data compared against age relevant normative data for dexterity (Agnew *et al.,* 1988; Desrosiers *et al.,* 1995) and grip strength (Dodds *et al.,* 2014).

Activities of Daily Living: Lifting, pouring and precision tasks involved in this study are summarised in Table 1 and included hand activity tasks used in other hand capability tests such as the Box and Block Test and the Sollerman Hand Function Test (Sollerman & Ejeskär, 1995).

Procedures: Prior to undertaking this study, the informed consent and safety of all participants was confirmed. Participants then completed a CanTab Motor Screening Test to ensure they possessed sufficient capacity to perform the experimental tests by screening for visual, movement and comprehension difficulties. All participants completed all task conditions with the task sequence counterbalanced to control for practice effects. Single handed everyday tasks and capability tests were performed with participant's dominant hand.

Task Performance & Task Quality Measures: Lifting tasks involved moving box and plate objects between different quadrants with task performance measures including task completion and task duration (time). Task Quality measures included the number of dowels which remained up during lifting tasks. Pouring tasks involved the same task performance measures as lifting tasks and task quality measures being the amount of water spilled during the pouring tasks.

Table 1: Experimental variables

Experimental Variables & Task Conditions	Research Study
1. Age	
1.1 Age Categories	
• 18-59; 60-69; 70-79 & 80+	⦿
1.2 Sample per age category	
• N=15	⦿
1.3 Total Sample	
• N=60	⦿
2. Hand Action Framework (HAF)	
2.1 Hand actions captured by HAF	⦿
3. Activities of Daily Living	
3.1 Lifting Tasks	
• Plate (Light/Heavy)	⦿
• Box (Light/Heavy)	⦿
3.2 Pouring Tasks	
• Small Cup with handle	⦿
• Large Cup (no handle)	⦿
• Large Cup with handle	⦿
• Drink Bottle (Light/Heavy)	⦿
3.3 Precision Tasks	
• Put key into Yale lock, turn 90 degrees	⦿
• Pick up coins & put into purse on wall	⦿
• Pick up nuts and put on bolts	⦿
• Write with a pen	⦿
• Fold paper, put in envelope	⦿
• Put paper clip on envelope	⦿
4. Capability Measures	
• Jamar Power Grip Strength Test	⦿
• Purdue Pegboard Dexterity Test	⦿
5. User Cost Measures	
• Manual Task Difficulty Scale	⦿
• Borg CR 10 Hand Exertion Scale	⦿

Participants: Distribution of ages within each age group summarised in Figure 3.

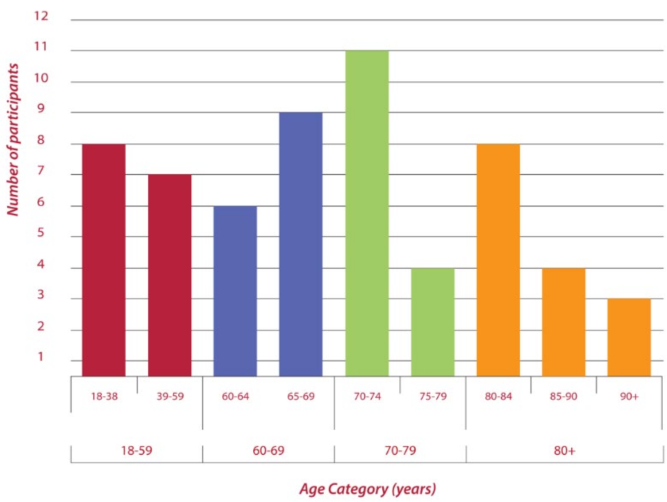

Figure 3: Distribution of ages within each category

Results and Discussion

A hand strength x dexterity framework was developed to illustrate the relationship between capability and task demands which demonstrates how capability and task demands can be framed to illustrate the relationship between them (Figure 4).

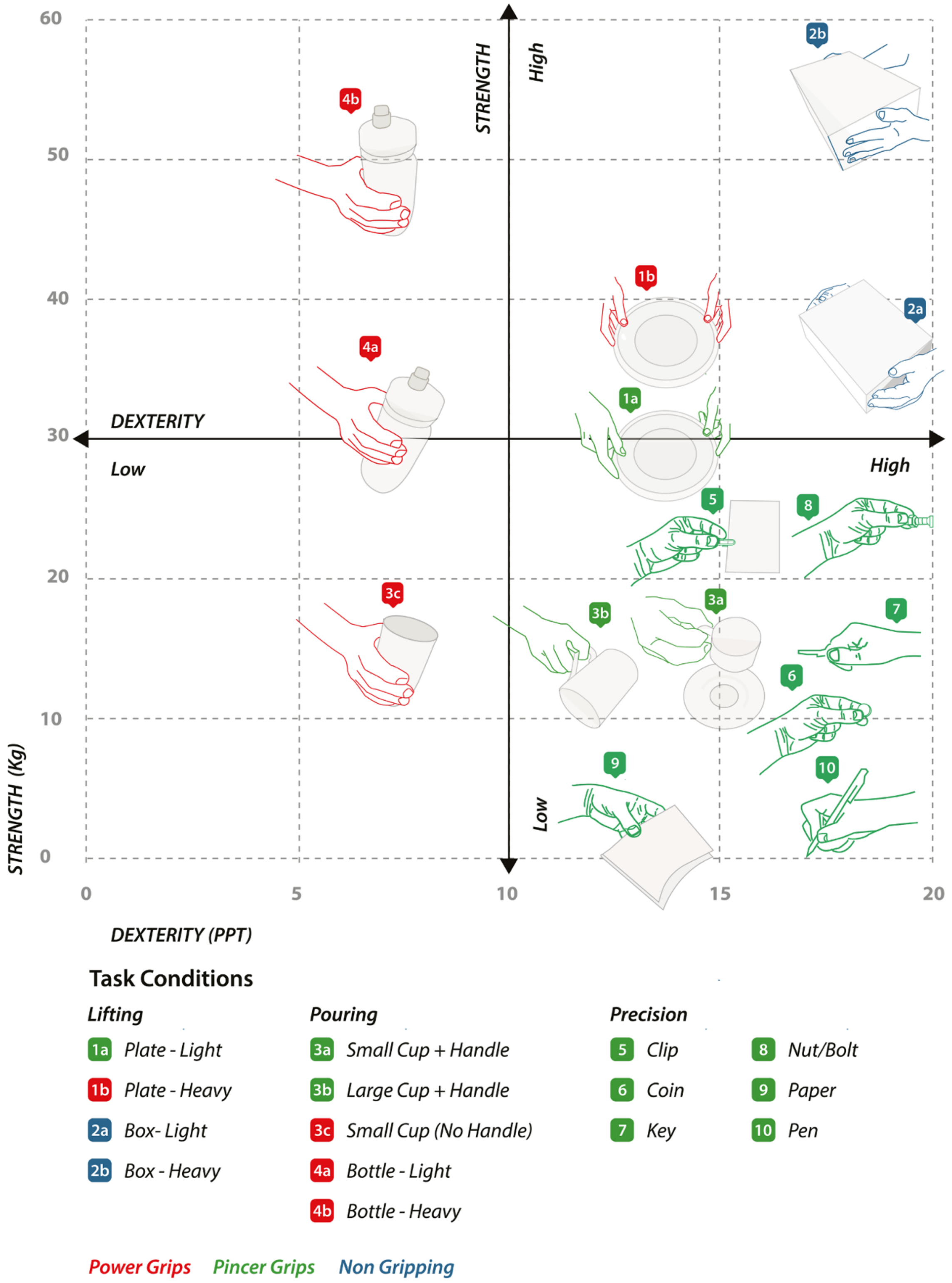

Figure 4: Tasks within this study expressed within dexterity x strength approach

This was used as the basis to estimate performance, difficulty, user cost and exclusion from performing everyday tasks for people of different ages to explore how the abovementioned factors may vary with increasing age.

Mapping "capability envelopes" to the task demands in Figure 5 illustrates the 18-59 age group capability is generally high strength and dexterity and is close to task demands for the strength-based box and precision key task. In contrast, 80+ age group capability envelope is significantly below task demands.

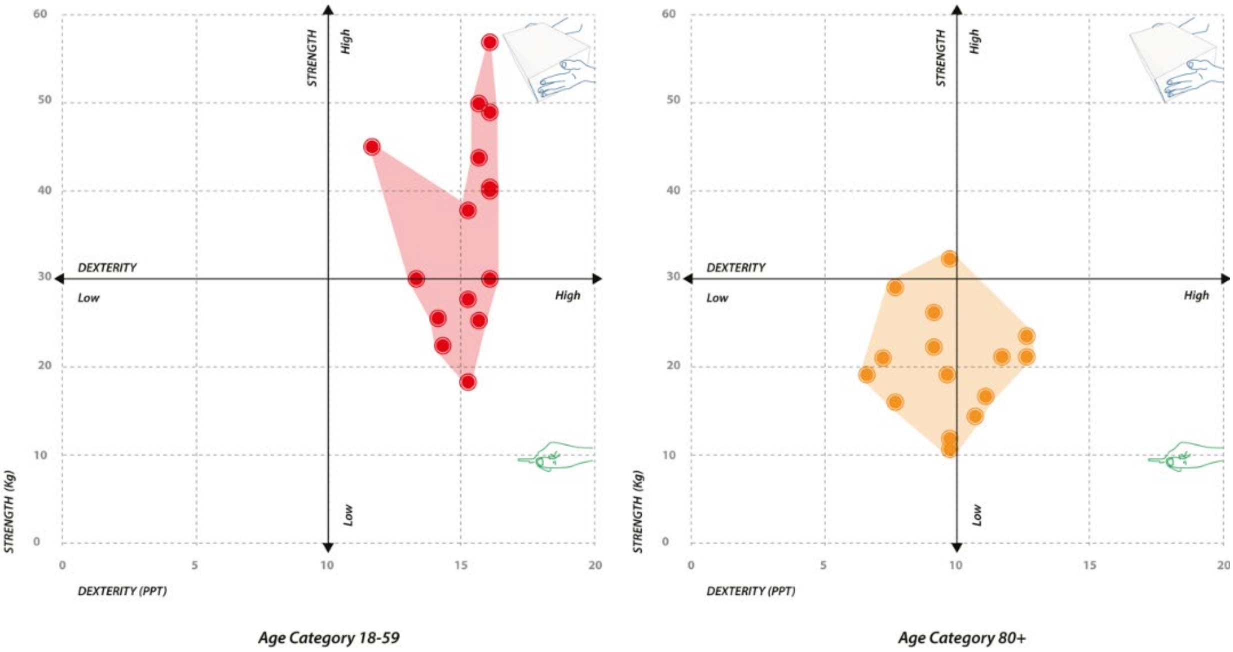

Figure 5: Strength x dexterity data, 15-59 vs 80+ years

The notion of an age-based strength x dexterity "*capability envelope*" mapping against task demands enabled the gap between capability and task demands to be recognised. In the case of older users (80+years) it is clear from Figure 6 their strength and dexterity capabilities are much lower than the youngest participants (18-59 years) and much further from the strength and dexterity task demands.

ANOVA results indicated this more substantial gap between both strength and dexterity capability compared to task demands resulted in an increased level of "Task Exertion" reported by the 80+ years compared to any other age group for Box (F=68.95, p <0.001), Plate (F=58.57, p <0.001), Bottle (F=18.75, p <0.001) and Precision tasks (F=27.37, p <0.001).

The same pattern of ANOVA results was achieved for the "Task Difficulty" measure where older participants (80+ years) reported higher levels of task difficulty compared to all other age groups for Box (F=20.34, p <0.001), Plate (F=60.76, p <0.001), Bottle (F=28.47, p <0.001) and Precision tasks (F=22.57, p <0.001).

The cup pouring conditions did not have a significant effect for age for both "Task Exertion" and "Task Difficulty" measures suggesting the smaller / lighter cup objects combined with the relatively simple motor task of pouring was independent of age in terms of the reported difficulty and exertion associated with this task.

As noted above, not only did older participants (80+ years) have significantly lower strength and dexterity capabilities compared to younger participants, but they also reported higher levels of "Task Difficulty" and "Exertion" to complete the plate, box, bottle and precision tasks.

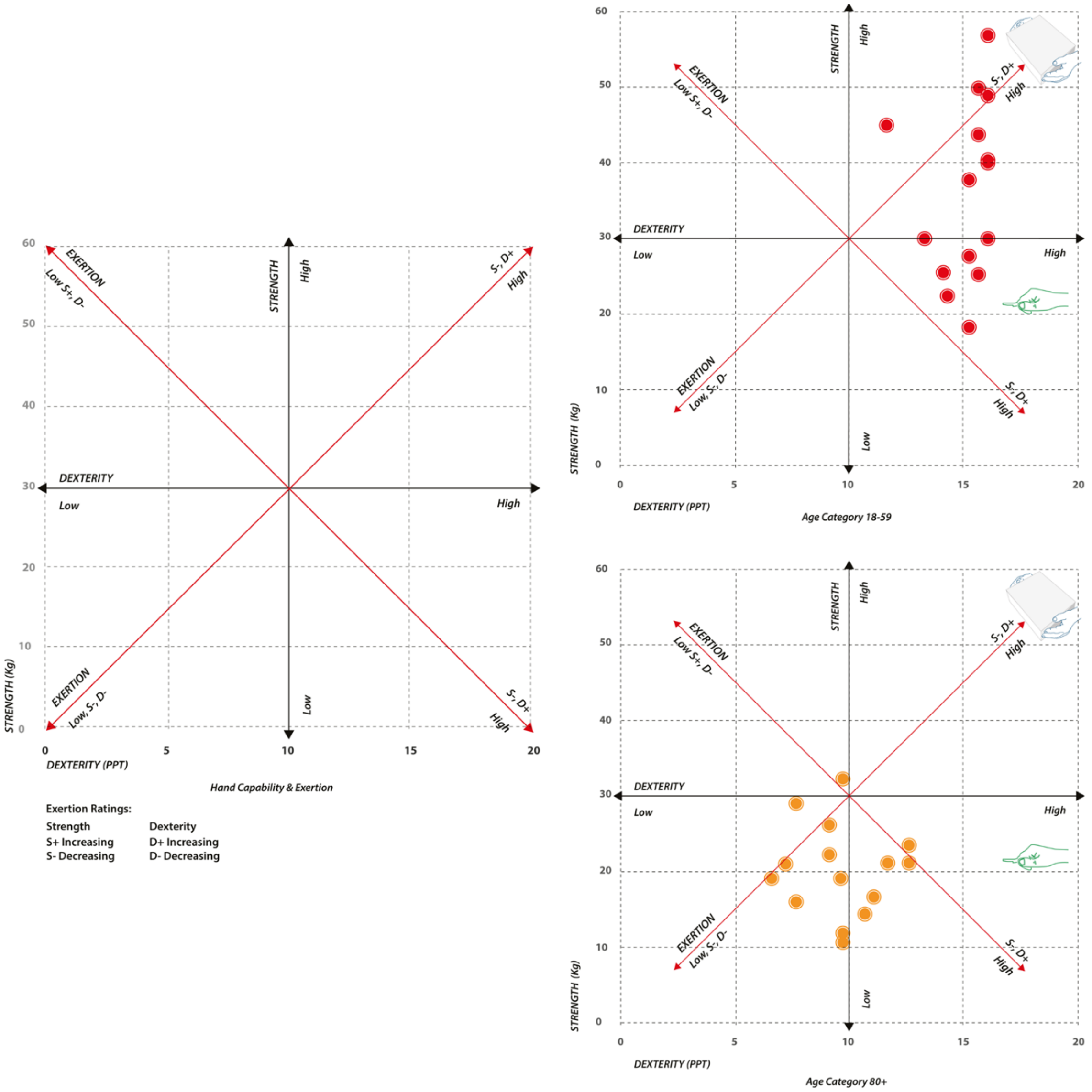

Figure 6: Strength x dexterity and exertion in context of capability – task demand analysis

Furthermore, these older participants also recorded the lowest "Task Quality" results of all age groups across all of the abovementioned conditions. This suggests older participants lower strength and dexterity capabilities required the highest levels of exertion and reported difficulty to complete the task, but task completion was at the expense of task quality which ended up being the lowest of all age groups.

What was learned from this experimental exploration of the Hand Action Framework is the "*strength x dexterity*" framework is an important way to characterise hand capability because it informs the relationship between capability and task demands. Furthermore, the integration of user cost measures of exertion and multifaceted measures of performance (e.g. Task Quality) have enabled an examination and explanation of the Performance Shaping Factors impact of task demands, age and capability on performance achieved, difficulty experienced and potential exclusion from everyday tasks.

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