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## **Evaluation of an assistive technology product design using a paired comparisons method within a mixed methods approach: A case study evaluating preferences for four types of cutlery with 34 upper limb impaired participants**

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
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# **EVALUATION OF AN ASSISTIVE TECHNOLOGY PRODUCT DESIGN USING A PAIRED COMPARISONS METHOD WITHIN A MIXED METHODS APPROACH: A CASE STUDY EVALUATING PREFERENCES FOR FOUR TYPES OF CUTLERY WITH 34 UPPER LIMB IMPAIRED PARTICIPANTS.**

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## **Abstract**

The purpose of the study was the assessment of preferences for 4 types of assistive technology (AT) domestic cutlery with 24 female and 10 male participants who had a range of upper limb impairments. A mixed-methods methodology, that included a paired comparisons analysis, was used to inform product development. Qualitative and quantitative data collected at the time provided triangulation of cohort preferences and insight into the reasoning of the participants. The results indicate that a high friction surface on AT cutlery handles is useful for all upper limb impaired users; however, the unconventional shapes of the Caring Cutlery better match the grip patterns generated by those with Arthritis. Conventionally shaped handles are favoured by those who generate conventional grip patterns. Statistical analysis of the paired comparisons results indicated a clear preference for the Caring Cutlery by those with Arthritis. The Etan cutlery set was favoured by those using one hand that predominantly had Hemiplegia following a Stroke. The paired comparisons method was used as part of a mixed methodology that was considered to be cost effective. The authors concluded that the methodology was useful to help validate a new inclusive/universal product design when the desired attributes are not accurately known.

## **Implications for Rehabilitation**

- An insight into the preferences of a UK population who have upper limb impairment affecting the use of AT cutlery;
- Generic heuristics to optimise AT cutlery described;
- A more effective methodology for AT product evaluation; and,
- A more robust basis for AT product design and development decision-making.

## **Purpose**

The aim of this paper is to define for healthcare and AT product design practitioners user preferences for a range of AT cutlery sets; and, offer reasons behind their opinions. The efficacy of the application of a mixed methods approach [1], focusing on a paired comparisons method [2] will be discussed in relation to the definition of user preferences for an AT product.

There is a wide-range of existing AT cutlery products from which end users and healthcare practitioners may choose. In a previous study a range of popular proprietary AT cutlery were compared against a then new design of AT cutlery. [3] In this study the two most popular cutlery sets from the previous study were compared with the same new cutlery and the user's own cutlery involving a larger sample of users.

The methodology combines empirical (observation/measurement-based) data collection methods with the qualitative method of eliciting first response that may be

processed using non-parametric statistics. The outcomes of the combined methods provide professionals with a basis for making decisions when no obvious measurement of a product's overall performance is available, in this case AT cutlery

This methodology, exemplified by Creswell [4], combines the philosophical approaches of both quantitative (experiment, numbers-based) and qualitative (case study, word-based) methodologies. The term methodology is used here to describe a number of methods with an approach. Creswell describes both methodologies being used 'in tandem'. The mixed methods methodology provides a practitioner with an information-rich resource with an opportunity to triangulate outcomes and gain further insight into questions posed. This leads to the validation of a product design. A mixed methods approach is particularly useful within AT product design and development, where there are limited numbers of participants available to provide a designer with insights or validation of design decisions.

Design decisions are often embodied in a physical product artefact. The collection of qualitative and quantitative data from a group of participants provides the AT designer with an insight into the reasons behind a participant's interaction performance; their behaviours and preferences. It has been the authors' experience that the outcomes of a small-scale (pilot) study provide enough information to make informed design-decisions, even though they are not usually statistically significant. Using paired comparisons within a mixed methods approach does offer the opportunity to gain some statistically significant validation from a relatively small sample group.

Paired comparisons, sometimes called pairwise comparisons, is a hierarchical ranking scale assessment method or test instrument which enables design practitioners to gauge the success of their design solutions against other similar products within the target market. The technique presents each participant with every possible pair of similar components taken from a set of design solutions and then requires them to state a preference for one item in each pair. This measurement method or instrument was first proposed by Thurstone. [5]

Böckenholt [6] highlights three benefits of using this test method/instrument:

1. It imposes minimal constraints on the judge (participant), especially when differences between items are small, and is less prone to the influence of context;
2. Internal consistency checks are available that identify judges (participants) who discriminate (choose) poorly; and,
3. It provides rich data about the effects of individual differences and perceived similarity relationships among items.

Böckenholt also highlights that there are drawbacks in using this method to test products. When multiple paired comparisons are undertaken by each judge (participant) the data may contain not only variations between each participant, but also variations at each moment during the test of all the items.

Variation or variability is a common issue within quantitative (non-parametric) testing; unidirectional variability arising from a confounding variable is called bias. Greer and Mulhern [7] define four generic causes of variability that may be found in the application of the paired comparison method/instrument:

1. Sample variation
2. Individual variation
3. Situation variation
4. Measurement variation

The following method described provides detail of steps taken to reduce variability/bias.

## **Method**

Cutlery sets were assessed by 24 female and 10 male participants who had a range of upper limb impairments. 3 of the females and 4 of the males were unable to use a knife and were classified as being “very impaired”, the remainder being classified as being “impaired”. The series of measurements and evaluations were approved by the University ethics committee. [8] All participants were recruited from within a 20

mile radius of the University. Participants were recruited through local charity groups supporting specific medical conditions, e.g. Arthritis Care. [9]

One female operator made appointments to meet with the 34 participants in their homes. Undertaking the mixed methods methodology in the participant's home reduced stress and enabled them to consider the cutlery in the context within which it would be used. All interviews were undertaken within working hours to reduce the influence of early morning or late evening fatigue on the participant. Due to the nature of their conditions, many of the participants needed more time in the morning to prepare themselves for the day; this constrained the available working hours for the interviews to 10.00am until 4.00pm. Each participant was asked to make the cutlery they used currently available for the comparison.

All participants were screened to ensure they had limited grip strength and or limited dexterity in one or more hands. Also, those who had skin conditions or associated medical conditions that may be affected by the handling of different types of cutlery were screened out. The associated medical conditions enabled the sample group to be treated as having been drawn from the larger United Kingdom (UK) population who have a similar condition. Through the recruitment process, the operators had gained an understanding of each participant's associated medical condition.



A combination of qualitative and quantitative measurements and assessments characterised the participant and their performance. The methods for collecting information included:

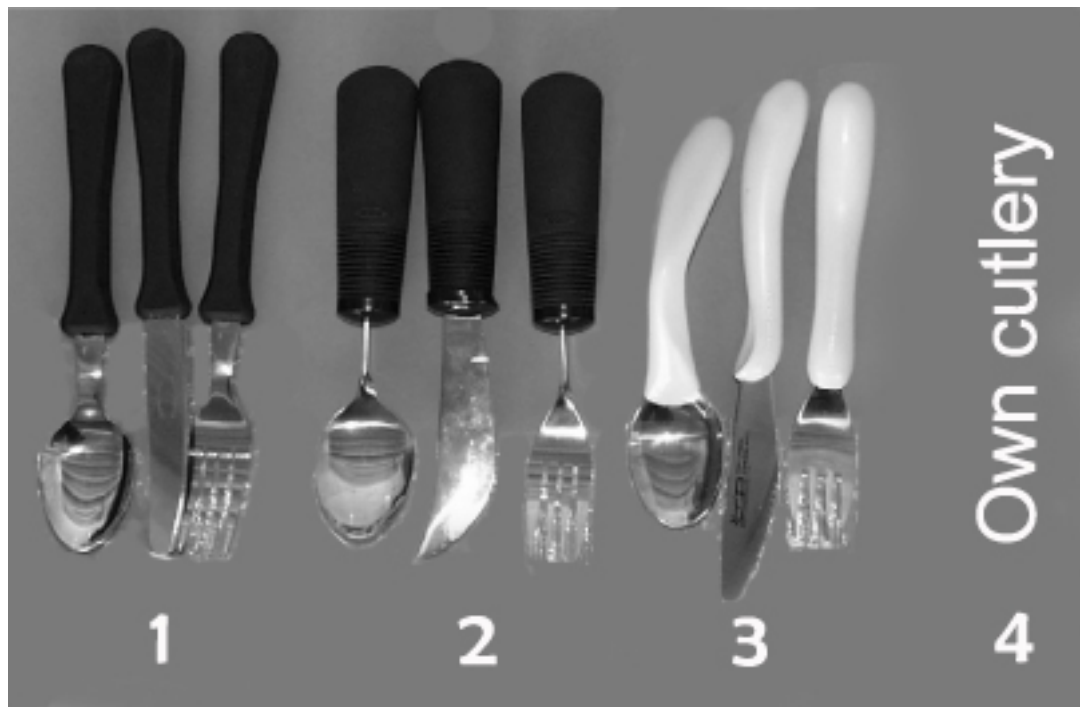
- A questionnaire relating to age, gender, lifestyle
- Anthropometric measurements of stature, upper limb and hands; and,
- Grip strength.

Age gender and lifestyle information enabled operators to link aesthetic preferences to existing market research resources, e.g. National Statistics Office. [10]

Anthropometry and grip strength information allowed operators to relate participants to other sample populations of larger studies of scale and strength, e.g. Adult data.

[11] The recorded characteristics placed each participant within a larger societal group; in this case, a UK population. All participants were able to provide an informed preference (judgement) for usability and aesthetic features.

The paired comparisons method was applied to 4 types of assistive technology–based domestic cutlery; Etan Cutlery, Caring Cutlery Good Grips and the participant’s own cutlery set, (See Figure 1.).



**Figure 1.** Shows the cutlery ranges to be tested: (1) Etan Cutlery, (2) Good Grips, (3) Caring Cutlery (4) the participant's own cutlery (multiple types not shown).

The operator had the four sets of cutlery, set out by their side, away from the participant. This was done so that the participant could not see the four cutlery sets, thus reducing any distraction. The operator had a pre-defined sequence of combinations so that each set of cutlery was presented for comparison with each other set. The participant was able to hold the knife, or fork or spoon, before comparing that sensation with the next being compared.

The test was designed to take no more than 36 minutes, with the overall interview taking no more than 60 minutes (including introductions and set up). This had been trialled with able-bodied participants to assess timings. In total there were 18

possible comparisons (6 pairs extractable from 4 sets multiplied by 3 items per set) made by each participant. This number of comparisons was considered to be a maximum before fatigue and boredom would become noticeable within participants responses.

When interviewing the next participant, the operator moved on the predefined combination by one pair, e.g. the starting pair for comparison was cutlery set 2 and 3, for the next participant it would be 3 and 4. This reduced overall bias arising from any treatment (ie. statements made, body language of the operator or learning by the participant); creating a condition in participants which influenced their response to the following treatment. Comments made by each participant as they went through the interview and paired comparisons were recorded on a Dictaphone.

Using the same sentence and tone of voice the operator presented the two sets of cutlery for visual and handling assessment. Use of the same sentence and tone of presentation reduces bias e.g. *'Taking your first impression only, choose one of these sets of cutlery over the other.'* The choice was recorded and the next combination presented. This procedure was repeated until all 18 combinations had been presented. The operator noted the results on a recording sheet.

The results of the interviews, measurements and paired comparisons were transcribed. The spreadsheet was linked with a further statistical processing of the results from each paired comparison.

Data preparation was in 2 stages: Stage 1) Data, in this situation the set preferred by each participant, were recorded onto a spreadsheet. Stage 2) The preferences were translated into entries on a statistical processing software spreadsheet in a format which enabled them to be processed using standard statistical tests; in this example, the Friedman and Kruskal-Wallis tests. [12] The format was (a) all data for a given participant being in the same row (to avoid violating the assumption of independence of cases) and (b) all measures of preference for the same thing being in the same column (to keep all data from the same sample together).

Following are the outcomes of the data recorded and processed from the applied mixed method approach and specifically paired comparisons method. It should be noted that the significance or non-significance shown in the tables may be related to the following guidelines.

Significance,  $p \leq 0.05$ , shows that the data is of acceptable quality for use as evidence. It "validates" the results (test output), but it does not validate any conclusion regarding cutlery; it is the quality of the experimental design and its conduct which will either do this or fail to do it. Significance does not mean that the experimental effects (say differences of preference) of interest are large enough to be of use; this is a judgment made by the researcher using results that are significant.

Non-significance,  $p > 0.05$ , strictly implies that no conclusions can be drawn using the results (because there is an unacceptably high risk that what appears to be experimental effect is really just part of the noise). However, provided that non-significance is flagged, it is reasonable to comment on what the results would have shown had they been significant; for this purpose, as a 'rule of thumb', results for which  $0.05 < p \leq 0.4$  may be used. For  $0.4 < p < 1$ , sample sizes needed to obtain significance are likely to be too large in this context (and/or effect sizes are likely to be too small). This makes some sense because results will always be significant if sample size is large enough - hence significance is saying that sample size is acceptably large for making inference to a population.

The way in which the statistical data is shown in the results (Table 3 onwards) is according to a convention where: Mean ranks shows a value from the comparison with the other cutlery sets; N is the number of participants;  $\chi^2$ , Chi Squared, is the test statistic used to determine the significance of the comparison; df describes the degrees of freedom within the test; and, p is a probability defined as the obtained value of statistical of significance (0.05 being the criterion or critical value such that statistical significance is obtained if  $p \leq 0.05$ ).

## **Results**

The study results are presented in two parts: 1) the results of the paired comparisons assessment and other recorded outcomes; and, 2) time resources used to undertake

the assessment and processing activities. There were 27 participants taking part (identified as Impaired Grip in the Tables) with an additional 7 of who could use only one arm to eat with the cutlery (identified as Very Impaired Grip).

**Table 1.** Provides an edited version of the data collected about individual participants. Note: 'none' indicates no grip possible to register using a grip dynamometer.

Participant Id	Gender	Age	Dynamometer (kg)	Stature (mm)	Hand Length(mm)	MCP (mm) Hand width	MCP (mm) Hand depth	Left, right or both hands used for test?	Main condition(s)
1	F	30	9	1550	172	76	24.45	B	RSI
2	M	49	1	1450	179	76	21.5	B	RSI
3	F	64	1	1575	175	79	27.28	B	RSI
4	F	58	11	1680	165	84	23.72	B	RSI
5	M	54	18	1780	196	89	28.54	B	RSI
6	F	56	8	1570	182	86	27.4	B	RSI/ Arthritis
7	F	39	1.5	1580	165	74	27.93	R	RSI
8	F	39	23	1720	172	76	24.74	B	RSI
9	M	61	10	1780	195	88	31.26	B	Arthritis
10	F	87	12	1370	172	86	28.74	B	Arthritis
11	F	87	1	1574	174	79	33.52	B	Arthritis
12	F	68	15	1730	180	75	N/A	B	Arthritis
13	F	73	none	1574	151	76	34.4	L	Polio
14	F	72	25	1625	185	85	27.71	L	Stoke
15	F	76	15	N/A	175	83	28.67	R	Stoke
16	M	36	none	1850	192	88	N/A	L	Brain damage
17	F	50	26	N/A	179	85	27.57	L	MS
18	M	67	21	1727	164	91	31.71	B	Parkinson's
19	F	86	15	1574	169	84	29.18	B	Arthritis
20	M	28	none	N/A	183	91	N/A	R	Cerebral palsy
21	F	65	28	1630	172	83	25.7	B	Encephalitis
22	F	72	35	1550	172	75	27.13	L	Stoke
23	F	70	22	1580	172	78	29.52	R	Stoke

24	M	74	36	1855	204	93	31.58	L	Stoke
25	M	67	26	1700	187	93	27.89	L	Stoke
26	F	85	5	1727	191	87	29.45	B	Brain damage
27	M	80	none	N/A	N/A	N/A	N/A	R	Arthritis
28	F	80	8	N/A	170	88	30.64	B	Arthritis
29	F	84	10	1574	173	98	29.19	B	Arthritis
30	M	72	29	1778	185	89	N/A	B	Parkinson's
31	F	76	5	1524	157	79	26.7	B	Arthritis
32	F	74	19	1803	176	81	21.42	R	Stoke
33	F	61	12	1536	175	86	26.38	B	Arthritis
34	F	73	10	1549	170	83	22.91	B	Stoke



**Table 2.** Shows a selection of transcribed comments made by the participants about the cutlery reviewed.

<b>Etan (set 1)</b>	<b>Good Grips (set 2)</b>	<b>Caring (set 3)</b>	<b>Own (set 4)</b>
<p>Knife and fork quite nice, like length. Comfortable for right hand. Like rubber. Looks like a disabled knife and forks but not a criticism. Would feel a bit obvious as disabled. Worry rubber might perish or discolour or go dusty - need to know.</p>	<p>Short and ugly and not very comfortable. Where you put your finger on metal is too narrow and not well designed. Very old person might use them. Wouldn't be seen out in public with these.</p>	<p>Colour is appalling, looks cheap because of the plastic. Like little depressions, they are comfortable. Comfortable in palms. Like shape of spoon, advantage doesn't stick in hand. Wouldn't use in public. Like shape generally, particularly the spoon.</p>	<p>Generally uncomfortable, just used fork not very often. Vegetarian, has a teaspoon as well. Uses US style.</p>
<p>They are a little bit heavy and straight. It has got a good grip so you don't slide too much. Not particularly comfy - too rubbery.</p>	<p>I quite like the spoon. Not too long the No 1 set is a bit long for me. Too rubbery, they smell a bit rubbery. It feels reasonably light, the shorter length is a bit better. Probably the knife is a bit heavier than I would like. I like the fork and spoon. Would possibly use in a restaurant.</p>	<p>Awkward to use. The shape isn't right it doesn't feel right in my fingers (holds grips at the end). Not keen on the depressions. The fork is reasonable because I use it upside down. I don't get on at all with the spoon.</p>	<p>I would like the fork to be sharper, it is the right sort of weight and is easy to hold. The knife doesn't cut too well and is top-heavy. I prefer the feel of the metal. The spoon could be a bit more curved more like No. 2.</p>
<p>I don't get the same grip and they are too long. I prefer just the fork. I prefer the set to my own set. They are lighter I could easily get used to them. Quite a good grip from the material. The colour is perfectly OK, not so smooth.</p>	<p>I don't really like the feel of these, they are all too thick. I would prefer my own to these.</p>	<p>These handles have a nice feel to them, there is a good grip and they are light. I could eat in the conventional way with these rather than turn my fork upside down like I have to do with my own. I like the feel of the handle better than the rubbery handles. I think just ordinary washing up would keep those clean. This set is the best - if I were to buy some new cutlery I would choose that.</p>	<p>I can't get the pressure on - I have to use my fist. I cut up and then put the knife down and use the fork. Pineapple ring is difficult to cut with my spoon - I have to hold the spoon in my fist. Set 1 is too long. No 3 gives me a better grip.</p>

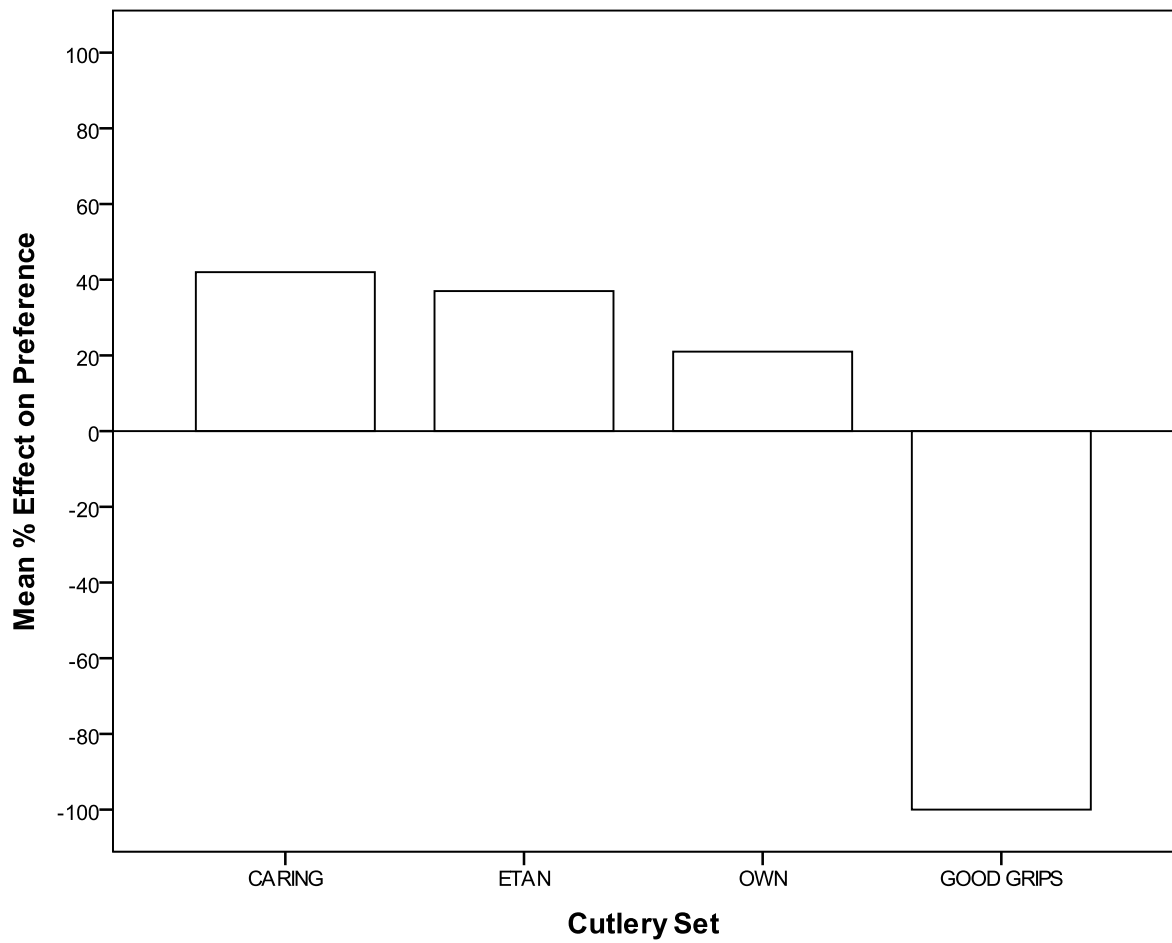
A selection of transcribed comments from the 34 interviews, shown in Table 2, provides an insight into the reasons behind the consensus of preferences for cutlery sets. Where similar comments were made repeatedly, they are represented only once in the Table.

**Table 3.** Shows the preferences, on average, between sets (i.e. for the group knife, fork and spoon) for 27 people with impaired grip.

			Mean Ranks Compared				Inferential Statistics			
Test	Grip	Utensils	Set 1	Set 2	Set 3	Set 4	N	$\chi^2$	df	p
Friedman	Impaired	Knife, & Fork, & Spoon	2.76	1.80	2.80	2.65	27	11.395	3	0.010

**Table 4.** Shows Table 3 mean ranks in terms of percentage of effect that Set differences have on Preference.

Knife & Fork & Spoon				
Set	Mean Rank	Grand Mean	Effect	%Effect
3	2.80	2.5025	0.2975	42
1	2.76	2.5025	0.2575	37
4	2.65	2.5025	0.1475	21
2	1.80	2.5025	-0.7025	-100



**Figure 2.** Shows percentage of effect that Set differences have on Preference (from Table 4).

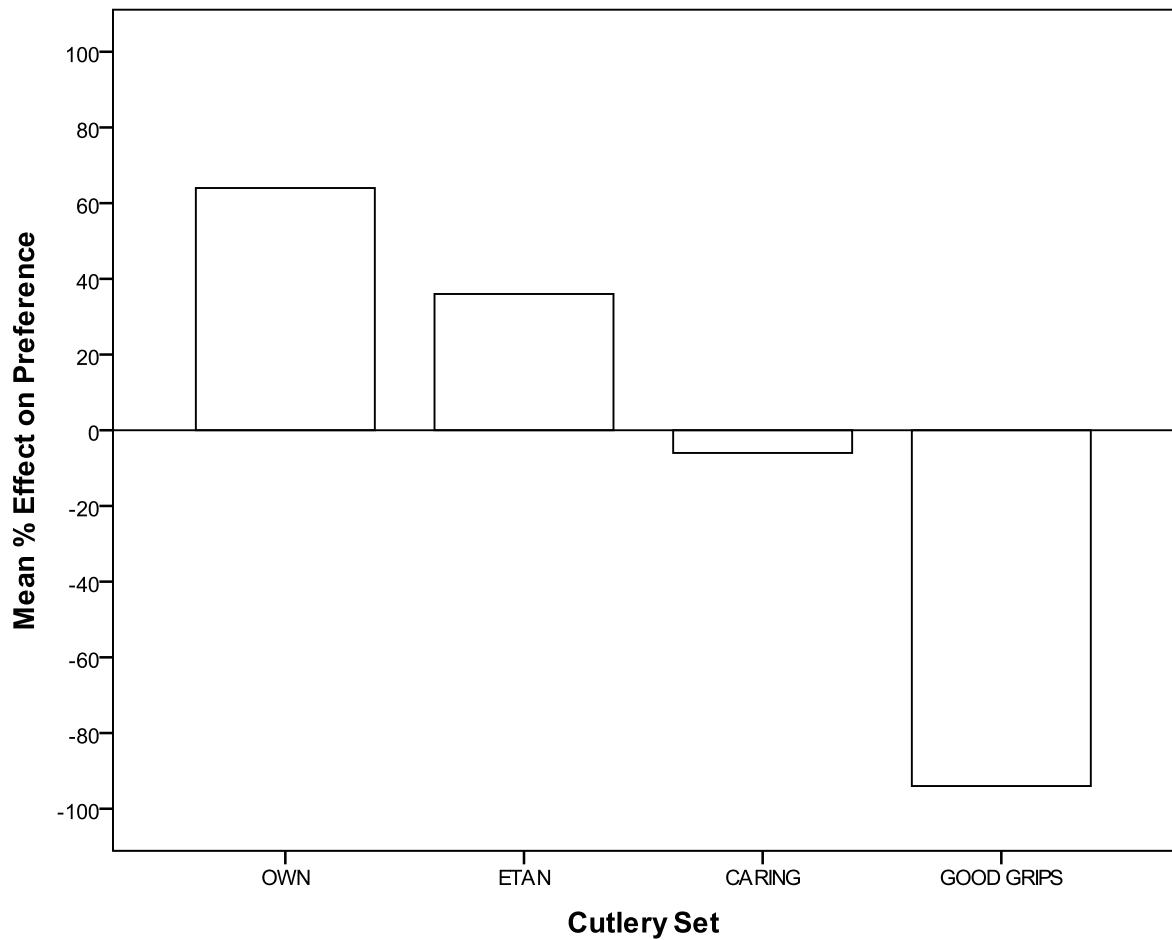
The impaired (two handed) group had a clear preference for the Caring cutlery, followed closely by the Etan set. Their own cutlery was placed behind these two sets. They had a notable dislike for the Good Grips cutlery set.

**Table 5** Shows on average, the preferences of 34 people with impaired and very impaired grip of fork and spoon set together when compared with other sets.

			Mean Ranks Compared				Inferential Statistics			
Test	Grip	Utensils	Set1	Set2	Set3	Set4	N	$\chi^2$	df	p
Friedman	Very Imp & Imp.	Fork & Spoon	2.68	2.03	2.47	2.82	34	7.861	3	0.049

**Table 6** Shows Table 5 mean ranks in terms of percentage of effect that Set differences have on Preference.

Fork & Spoon				
Set	Mean Rank	Grand Mean	Effect	%Effect
4	2.82	2.50	0.32	64
1	2.68	2.50	0.18	36
3	2.47	2.50	-0.03	-6
2	2.03	2.50	-0.47	-94



**Figure 3.** Shows percentage of effect that Set differences have on Preference (from Table 6).

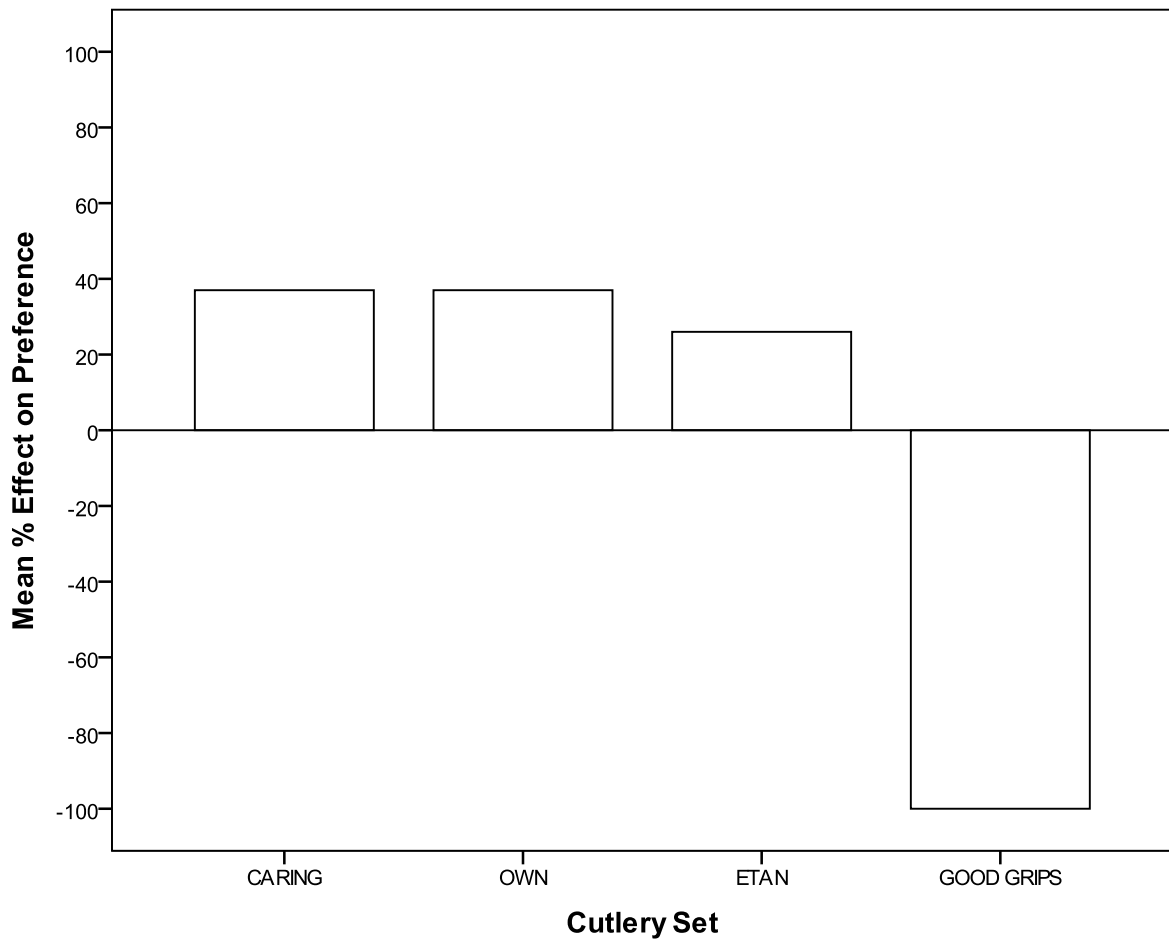
All 34 participants had a clear preference for their own fork and spoon, followed closely by the Etan cutlery set. The Good Grips cutlery was least preferred.

**Table 7.** Shows on average, the preferences of 27 people with impaired grip of fork and spoon set together when compared with other sets.

			Mean Ranks Compared				Inferential Statistics			
Test	Grip	Utensils	Set 1	Set 2	Set 3	Set 4	N	$\chi^2$	df	p
Friedman	Impaired	Fork & Spoon	2.67	1.85	2.74	2.74	27	9.944	3	0.019

**Table 8.** Shows Table 7 mean ranks in terms of percentage of effect that Set differences have on Preference.

Fork & Spoon				
Set	Mean Rank	Grand Mean	Effect	%Effect
3	2.74	2.50	0.24	37
4	2.74	2.50	0.24	37
1	2.67	2.50	0.17	26
2	1.85	2.50	-0.65	-100



**Figure 4.** Shows percentage of effect that Set differences have on Preference (from Table 8).

**Table 9.** Shows, on average, the preferences for 27 people with impaired grip between utensils (knife or fork or spoon) within each set.

Test	Grip	Set	Mean Ranks Compared			Inferential Statistics			
			Knife	Fork	Spoon	N	$\chi^2$	df	p
Friedman	Impaired	4	1.72	1.98	2.30	27	6.986	2	0.030

The impaired (two-handed) group preferred their own fork and spoon equally with the Caring cutlery, followed closely by the Etan set. Again, the Good Grips cutlery is least preferred.

**Table 10** Shows, on average, the preferences of 27 people with impaired grip for the knife when compared with the knives in other sets.

		Mean Ranks Compared				Inferential Statistics			
		For Knives							
Test	Grip	Set1	Set2	Set3	Set4	N	$\chi^2$	df	p
Friedman	Impaired	2.74	1.89	3.06	2.31	27	13.494	3	0.004

The knives from each set provided a clear preference for the impaired (two-handed) participants over the Etan and then their own knife. A clear dislike of the Good Grips knife is shown.

**Table 11** Shows, on average, the preferences of 34 people with impaired and very impaired grip for fork and spoon when compared between the sets.

			Mean ranks Compared				Inferential Statistics			
Test	Grip	Utensil	Set1	Set2	Set3	Set4	N	$\chi^2$	df	p
Friedman	Very Imp. & Imp.	Fork	2.71	1.99	2.69	2.62	34	7.927	3	0.048
Friedman	Very Imp. & Imp.	Spoon	2.54	2.24	2.25	2.97	34	7.789	3	0.051

Note: 0.051 is marginally non-sig.



The comparison of the forks by all 34 participants provided a significant result in preference for the Etan fork, followed closely by the Caring Cutlery and own fork, were shown with a clear dislike of the Good Grips fork. The spoon comparison provided an indicative result, with a notable preference for their own spoon, followed by the Etan spoon, then notably the Caring Cutlery and Good Grips spoon almost equally least preferred.

Each interview took approximately one hour; however, transport to and from each participant added another two hours, even with the optimising of the order of participant meetings to location. This resulted in only two interviews being conducted each day, due to the time constraints.

The measurements and introductory interview took approximately 20minutes. The paired comparisons procedure took approximately 36 minutes per participant for the 18 pairs. Where participants took longer over their decision-making participants were asked to give their first impression of each set on which they made their decision. It was noted that participants made decisions more quickly towards the end of each paired comparison session. Where participants were one-handed, only the fork and spoon from each set were used in comparison.

Post processing of the data took 16 working hours to transcribe from all the interview schedules. Four hours taken checking the transcriptions; some transcription errors

were found and corrected. There were a further four hours of transcription from Dictaphone comments and four hours of processing of the paired comparison data to provide some statistical validation of the results. A total of 28 working hours were used to post-process the results.

## **Discussion**

Tables 3, 4, 7 and 8 indicate that people with Impaired Grip (two-handed) preferred Set 3 of the standard sets (Caring Cutlery). Tables 5 and 6 indicate that people with Impaired Grip (one-handed, who could not use a knife) preferred Set 1 of the standard sets (Etan Cutlery) if they could not use their own set (set 4). The results given in Tables 9 to 11 provide details which are consistent with these findings. Comments made by the participants indicated that they found it difficult to orientate the spoon of the Etan and their own cutlery. In both cases the bowl of the spoon was not as deep as that found in the caring cutlery and good grips set. Material and shape of the handles were highlighted as important through both positive and negative comments relating to each Set. The contrast in comments indicates polarised views about the shape of Set 3 and material of Set 1 in particular.

Table 4 and Figure 2 show that, for people who could use both hands, overall preference is for Set3 (Caring Cutlery) with Set1 (Etan) coming close as the next preferred set of cutlery. Set 2 (Good Grips) stands out as being least preferred. This was positively disliked, which is supported by the qualitative data. Table 10

shows the same order of Set-preference for knives. For Set 4 (Own Set), the spoon is the most preferred utensil, then the fork, then the knife.

There are no significant results relating to people with very impaired grip (one-handed) on their own; most likely owing to the small sample size (N =7). However, there were some indications that may be drawn by comparing significant results for people with Impaired Grip (two-handed) and people with Impaired & Very Impaired Grips (all participants). The overall comparison between Sets must be done in terms of Fork & Spoon because the Very Impaired people could not use knives. Table 7 (for impaired) showed Set 3 and Set 4 as equal first in preference, followed by Set 1 with Set 2 being the least preferred. Table 5 for Impaired & Very Impaired shows Set 4 (Own Set) being preferred about twice as much as the next preferred Set 1.

The addition of Very Impaired people does not change Set 4 as first choice. But we know that, overall, the Impaired people alone prefer Set 3 in most situations, so it appears the addition of Very Impaired people caused a swing to cutlery Set 4 (Own) as first choice. Set 1 (Etan) was the second choice for both Impaired and Impaired & Very Impaired; the addition of Very Impaired people produced no change for the second choice.

If allowance is made for a large amount of habituation involved in the use of the non-standard Set 4, it would make cutlery Set 1 (Etan) the most preferred from the 3

remaining standard Sets for people with very impaired grip. Set 2 (Good Grips) was consistently the most disliked.

The addition of Very Impaired reversed the order of the two most preferred sets from Set 3 over Set 1 to Set 1 followed by Set 3. This suggests that Very Impaired people prefer Set 1 because of the perceived usability of the fork. The Caring Cutlery (Set 3) was most preferred by the two-handed participants when compared with the other cutlery sets. This contrasted with the one-handed participants who preferred the Etan and in some cases the Good Grips fork and spoon.

The reason for the notable preference for the more conventionally shaped Etan and Good Grips may be the high friction grip of the rubber elastomer handles. The one-handed participants in this study could make conventional grip patterns, but had weak grip, in many cases due to stroke. The Caring Cutlery set had a handle shape that fits more effectively with the grip patterns created by those with forms of Arthritis.

The additional 28 hours (3.5 days) of post-processing time were absorbed into the 15 days that the operator was undertaking the trials. Post-processing in between interview sessions was found to be a cost-effective way of using the 'down-time' between participant home interviews. The paper-based recording originally used was inefficient and resulted in data entry errors that increased the post-processing time. The post-processing of participants measurements and choices may be enhanced through the use of a pre-prepared electronic data sheet and laptop.

Recording directly into a spreadsheet reduces the possibility of mis-recorded data entries. However, additional cost may be added in the set up and additional time required when deadlines are likely to be tight. Having a generic paired comparison template would reduce much of the lead time in use.

## **Conclusions**

When specifying AT cutlery, a set with high friction material is desirable for all groups. For those with Arthritis, the unconventional shapes of the Caring Cutlery are more appropriate for the grip patterns associated with this condition. A conventional shape would be appropriate with those who had neuro-muscular conditions that impaired grip rather than change grip patterns.

Limitations of the cutlery sets identified during the assessment have been noted. An important limitation in the efficacy of the AT cutlery sets in general in the UK is that they are many times more expensive than their mainstream competitors. The cost of tooling for a small batch production along with recovering research and development costs add to the high retail price to the end user. Taking a Universal design approach to AT cutlery design may be one way to overcome this problem.

In terms of effective function the Etan is more conventional looking, whilst providing a useable high friction grip surface and handle shape. Whilst the Etan appears to satisfy many of the needs for those with weak grip it does not fully assist those with Arthritis. The shape, which appears more effective for those with forms of Arthritis is that of the

Caring cutlery. However, the cutlery is not well received socially by others within UK society. Elements that contribute to stigma that require addressing include an unusual shape coupled with a perceived association with medical products, due to the skin-tone handle colour. Based on comments made and tacit observations during the assessments, the conventional spoon bowl appears to require a deeper bowl for those with Arthritis. It appears this is due to a difficulty in articulating shoulder, elbow and wrist; even the bowl of the Caring cutlery may still be too shallow.

The paired comparisons method with associated statistical processing described is a simple technique which can be adapted to different design evaluation situations and which requires little additional training if the operator is already well-versed with user assessment. It can be used in a responsive way, as it does not involve investment in equipment or set up (with the caveat already mentioned). However, the quantitative technique, which enables preferences to be identified and generalised to a population, does not give the designer insight into why these preferences have been expressed. Qualitative techniques, which enable reasons to be identified for preferences, do not allow for generalisation to a population. Quantitative and qualitative techniques should always be used together to provide a holistic view of opinions about an AT product by a target population.

For any practitioners who lack confidence for applying this method, obtaining help from a statistician is advised. As discussed early in this article, there are a number of variations on data preparation and statistical processing for the paired comparisons method; the method described above incorporating the use of the Friedman and

Kruskal-Wallis tests being only one. Once in place, the method can be used with confidence for many applications. Used as part of a mixed-methods approach, a paired comparisons test can be a valuable asset to user-centred and evidence-based design practice.

A number of limitations of the methodology described and applied in this study have been identified. A limited amount of quantitative data was collected such as joint angles or direct force measurement, which could have been evaluated using a task analysis method. A formal collection of user comments, using a semi-structured interview after each comparison, could have provided more detailed qualitative data about the reasons behind the expressed preferences. The addition of these methods would enable a more robust mixed methods approach to be applied, along with additional opportunity for triangulation. However, some of these methods have already been applied within an earlier study. Combining the outcomes of this and earlier published studies provides a more comprehensive view of issues within AT cutlery design.

## **Future research**

The authors propose to undertake the development of an optimised design for AT cutlery for people with forms of Arthritis. The new design will address the functional needs as well as the social function or value of the cutlery. This design will address how to influence the perception of able-bodied people towards a more inclusive viewpoint of people who have impairments and are using AT products. This will include the research-based methods for validation of the design intervention. The authors are involved in the development of an optimised

methodology for an evidence-based AT product design. This study provides another component towards this approach.

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## **Declaration of interest**

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