Analysis and Evaluation of Visual Cues in Graphical Interpolators

Darrell Gibson
Faculty of Science & Technology,
Bournemouth University, UK
dgibson@bournemouth.ac.uk

Richard Polfreman
Faculty of Arts and Humanities,
University of Southampton, UK
r.polfreman@soton.ac.uk

ABSTRACT

Graphical interpolators provide a simple mechanism for synthesis-based sound design by offering a level of abstraction above the synthesis parameters. These systems supply users with two sensory modalities in the form of sonic output from the synthesis engine and visual feedback from the interface. A number of graphical interpolator systems have been developed over the years that provide users with different visual cues, via the graphical display. This study compares user interactions with six interpolation systems that have alternative visualizations, in order to investigate the impact that the interface's different visual cues have on the process of locating sounds within the space. We also present a dimension space analysis of the interpolators and compare this with the user studies to explore its predictive potential in evaluating designs. The outcomes from our study help to better understand design considerations for graphical interpolators and will inform future designs.

1. INTRODUCTION

A central challenge when undertaking sound design with a synthesizer is determining how to configure the synthesizer parameters to create a certain audio output, i.e. how to turn intended sonic characteristics into parameter values. All the more so as synthesizers often possess a large number of parameters with complex relationships to the sonic output.

Graphical interpolators offer a mechanism to simplify sound design by reducing control complexity through a *few-to-many* mapping between an interpolator and the parameters [1]. This is achieved by taking defined states of synthesis parameters ("presets") and associating them with locations within a 2-D graphical pane. Moving an interpolation cursor's position within the space results in new sounds being generated as the synthesizer parameters are changed by the interpolation model. This provides a mechanism to define a navigatable sound space which is constrained by the characteristics of the selected sounds, their locations in the space and the visual model used. Many different graphical interpolators have been developed, that provide users with a variety of visual cues, and in this work a number of these have been analysed and evaluated through user testing.

2. PREVIOUS WORK

Previously the authors undertook a review of a number of these interpolator systems and reimplemented them so they could be comparatively evaluated [1]. Examples of six of these are shown in Figure 1.

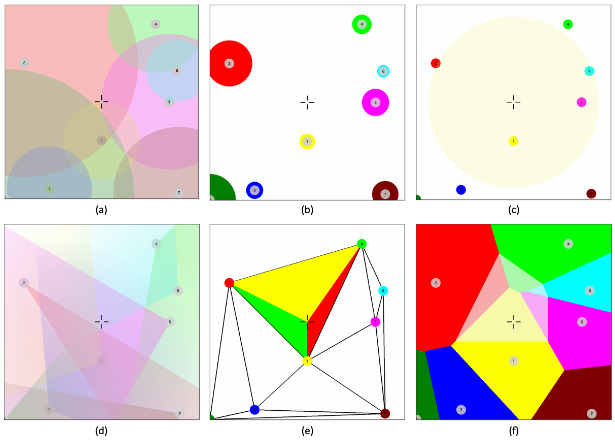

Figure 1 Visualizations for Different Graphical Interpolator Models: (a) Nodes, (b) Gravitational, (c) Radius-Based IDW, (d) Light, (e) Delaunay Triangulation and (f) Voronoi Tessellation

Figure 1a, is the *nodes* interpolator [2], where each preset is represented as a circular node and the interpolation is performed in the areas where the nodes intersect. Where there is no overlap between nodes the corresponding preset sound will be generated. The next interpolator (Figure 1b) is based on the INTERPOL control window from the SYTER system [3] which utilized a gravitational model where each preset is a *planet,* the size of which determines its *gravitational force* and so influence in the interpolation space. When positioned on a planet the gravity results in the preset sound. The third interpolator (Figure 1c) uses a radius-based Inverse Weighted Distance (IWD) model [4], where the distance to the preset locations is used for only those presets within a specified radius of the cursor. The interpolator shown in Figure 1d, uses a light model, where each preset corresponds to a lamp that emits a beam of light where the range and angle can be set. The interpolation is then performed where the light beams intersect [5]. The next interpolator (Figure 1e) uses the preset locations to form a Delaunay triangulation in the interpolation space [6]. The triangulation determines which three presets are included in the interpolation by using the vertices of the containing triangle. The relative weightings of each preset are shown as a coloured triangulation between the cursor point and the presets. The final interpolator, shown in Figure 1f, generates a Voronoi tessellation where each polygon represents a preset [7]. The interpolation is performed between the presets that are natural neighbours of the cursor location. The relative weightings are shown by the transparent "ghost" polygon centred at the cursor.

In the previous study it was shown that different graphical interpolator models result in the generation of unique sonic pallets that impacts on the range of sounds it is possible to achieve with a particular interface and configuration [1]. A separate study was undertaken to establish whether visual cues on a graphical interface aid the navigation of the interpolation space or could the same results be obtained without any graphics (i.e. a plain interpolation space) [8]. The results from this study indicated that the number of visual cues provided by an interface does impact on the interpolators' performance and perceived usability. Tabulated analysis was then undertaken of the visual cues each interpolator model in Figure 1 provides. It was found that although the interpolators share similar goals, their visual cues can be disparate [9].

Given that the previous work indicated a link between visual cues and usability, this study examines the models in Figure 1 that provide different cues, to assess their relative performance. To do this, we first propose a mechanism for the analysis of interpolator visual cues to see if commonalities and trends can be identified between different models. User testing was then undertaken to evaluate the impact that cues may have on the usability and performance of an interface. The results should allow future designs to leverage the potential of particular visual cues.

3. INTERPOLATOR DIMENSION SPACE

Dimension space analysis has previously been defined and applied to the design of digital musical devices [10], [11], as a means of visualizing differences between systems. These have defined spaces with seven and eight dimensions respectively, but were created for somewhat different instrument design contexts, based on phenomenological versus epistemological factors. Although a graphical interpolator can be used as a musical device it does not fit with the sound design application area of interest in this work. In addition, all the interpolators have similar basic functionality so it was unlikely that it would be possible to identify significant differences using the dimension spaces previously defined. Given the area of interest here is the visual cues that each model provides, a new six-axis space is defined, shown in Figure 2. Each of the axes is marked with a representative range and is described in detail in the remainder of this section. It should be noted that although the space has been primarily created to analyse the six interpolator visualisations in this study, care has been taken in the definition of the space to ensure that it is flexible enough to analyse other graphical interpolators.

The six dimensions are derived from earlier analysis [9] and each is made up of three discrete values that describe the requirements of the visual model or how the interpolator handles a particular visual cue. Note that where there are properties that are common to all the interfaces (such as, preset locations, handles, etc.), these have not been included in order to highlight only the differences between the interfaces.

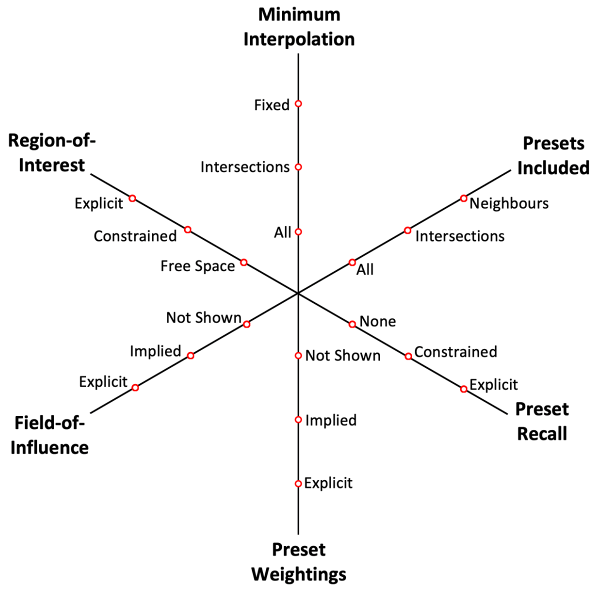

Figure 2 Six-Axis Dimension Space for Interpolator Visualisations

Where there are common discrete values on different axes, they have been positioned at the same locations and they have been arranged in order of increasing desirability, based on the findings from the testing already undertaken and the evaluation of previous systems [1, 8, 9]. In this way, the larger the dimension spaces radar plot is, the greater detail the visual cues provide on the interface. However, evaluation of the cues' actual desirability will need to be established through user testing. As far as possible, the axes have been arranged such that common values are on adjacent axes. The individual axis details follow, working from the origin outwards:

- **Minimum Interpolation** specifies the minimum requirement before the interpolation can be performed. The axis contains three discrete points: *all*, *intersection* and *fixed*. The first value, *all*, is used for those interpolators that perform interpolation between all of the presets within the space without any restriction, such as SYTER [3]. The *intersection* value is used where the interpolator needs the presets to be arranged within the space so that intersections occur, for example, as seen in the node [2] or light [5] models. The *fixed* value is used for interpolation models where a specific number of presets is required in order to perform interpolation. E.g., a triangulation model requires three presets to perform the interpolation [6].
- **Presets Included** indicates how an interpolator's visual model tells the user which of the presets within the space are included in the current interpolation output. The first value again represents the interpolation models where *all* presets within the space are included in the interpolation. The middle value, *intersections*, like the previous axis is for those systems that use some form of intersectional model, meaning the presets included in the

interpolation are those that intersect the current cursor position. The final value, *neighbours*, represents models where the interpolation is performed with presets that are neighbours of the cursor position, as in Voronoi tessellation [7].

- **Preset Recall** represents a model's ability to recall the original preset sounds unchanged. The first value, *none*, is for models where interpolation is always being performed and so it is not possible to hear the original presets. This is the case for models such as an unconstrained IDW [4]. The *constrained* value is for interpolation models where the layout of the presets may make it impossible to recall a preset. For example, with the intersecting models, such as nodes [2] the preset sound can be recalled if the interpolation point is positioned in a non-intersecting region of the preset's area. However, if the current layout does not offer a non-intersecting region, then it will not be possible to hear the original sound. The final value, *explicit*, is for models that have a specific location where the interpolation results in the recall of preset sounds. For example, with the gravitational model positioning the interpolation point on a planet's surface [3].
- **Preset Weightings** defines how the interpolator model shows the weightings of the individual presets included in the current interpolation output. *Not shown*, is for interpolators that have no visual cue to represent the individual weightings, as was the case with Interface 1 (no visualization) in the previous study [8]. The *implied* value is where the weightings are implied through the model. For example, with IDW the individual weightings are implied by the distance between the interpolation point and the included presets [4]. The *explicit* value is where the interpolator provides an obvious visual cue showing the individual weightings. For example, with INT.LIB weightings are shown visually by linking to the transparency of the presets [12].
- **Field-of-Influence** indicates an interpolator's ability to display the range of each preset within the interpolation space. The point *not shown* is used for interpolators that give no indication of a preset's range, as would be the case with interface 1 (no visualisation) or 2 (preset locations) from the previous study [8]. The next value is *implied* and is used where the range is not directly shown but is implicit by the preset's position relative to the other presets. This would be the case for interpolators such as those that use some geometric arrangement of the presets [13]. This leaves the final value of *explicit* which is used for the interpolators that show the extent of each preset, such as the light model [5].
- **Regions-of-Interest** represents how the visual model shows the areas where the interpolation is being performed. The first value, *free space* is used for interpolators that can perform the interpolation across any area that is not a preset location, as is the case for SYTER [3]. The next value, *constrained* is used where the free space is restricted in some way such as being contained as in the case for the radius-based IDW or proximity of neighbour as with Voronoi tessellation [7]. The final value *explicit* is where a region is clearly shown either by a containing shape as with triangulation interpolation [6] or as an intersectional area as with nodes [2].

3.1 Analysis of Interpolator Dimension Spaces Plots

Having defined a dimension space for graphical interpolators, this was then applied to the six reimplementations. Each was analysed against the six dimensions defined and a plot generated. For comparison these are shown in Figure 3.

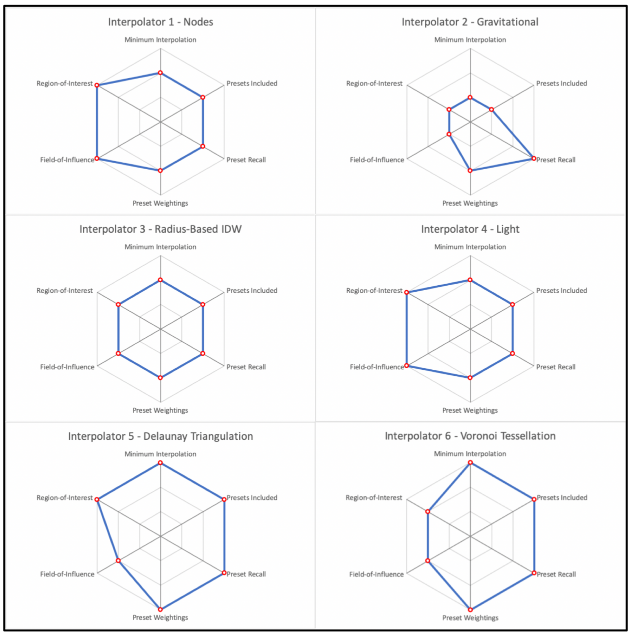

Figure 3 Dimension Space Analysis for the Reimplemented Interpolators

From this analysis it is noticeable that the gravitational model (Interpolator 2) results in a plot with the smallest area as most of the axes get the minimum score. The exceptions being *preset recall* for explicitly allowing the source presets to be recalled and *preset weighting* as this is implied by a distance function. As the values have been arranged along each axis with increasing desirability, plots that are focused on the origin could be considered less ideal than those that are wider. In this case, the gravitational model appears to be the least suitable as it does not provide the user with as many visual cues as the others. The next widest plot was for Radius-based IDW (Interpolator 3) which has the middle value on all the axes, suggesting it is preferable to the gravitational model, but not as favourable as the others. The two interpolators that both use intersecting models, nodes (Interpolator 1) and light (Interpolator 4) both produced identical plots for the defined dimension space. This is perhaps not surprising as the light model's angular component is the only significant difference between them. Both gained the highest score on two axes for explicitly showing each preset's *field-of-influence* and *region-of-interest*. The Voronoi tessellation (Interpolator 6) generated the next widest plot, having the highest value on all the axes apart from two: *field-of-influence* and *region-of-interest*, the two axes that the intersecting models achieved the highest values on. Finally, the triangulation (Interpolator 5) produced the plot with the widest area, with the highest value on five of the six axes, but only achieving the middle value for *field-of-influence*. The fact that the last two models which featured the widest plots are the geometric duals of each other [14] may be of importance.

3.2 Evaluation of Dimension Space Results

The dimension space analysis provides a pictographic representation of the visual cues offered by each graphical interpolator. It has also allowed ranking of the interfaces against a scale of desirability and forced consideration of which characteristics might be advantageous when designing new graphical interpolator interfaces. However, it should be noted that the scale of desirability used for the plots is solely based on the result of the author's bench testing and the previous evaluation undertaken [1]. Also, with this method of dimension space analysis there is an assumption that each axis is of equal importance in the plot, which may not in fact be the case [15]. Nonetheless, the plots do offer an effective way to directly compare multiple interpolators that all have the same base functionality. To verify the outcomes from this analysis and to gather quantitative data, usability testing was undertaken, using a similar methodology to that used previously [8].

4. INTERPOLATOR EXPERIMENT

An experiment was designed to establish if there was an identifiable difference in the way that users interact with each interface. The aim was to determine if the different visual cues influence the system's performance. The same metrics used in the previous study were chosen as it was shown that the total test time, speed of cursor movement and distance moved all increased with visual cues [8]. However, in the previous study the participants were asked to locate a specific sound while in this experiment there is no "correct" location, so the user-selected locations will be used to determine the distribution of locations that produce suitable sounds. Using these metrics should provide insight into differing user interactions with each interface and through the dimension space analysis, a relationship to the visual cues the interface provides. Comparative testing was undertaken with the six reimplemented interpolators. As well as examining how users interact with each visual interface, the experiment also attempted to see if the different visual models had an impact on the sound design. To achieve this, for each interpolator the participants were given a written "brief" detailing the type of sound required, a visual reference of where the intended sound will be used and an aesthetic context for the sound. To ensure some comparability between the sound design tasks for each interface, the type of target sound was kept the same, allowing identical preset sounds to be used with each interpolator. To provide some diversity in contexts and potential sonic solutions, the type of sounds chosen were background ambiences for spacecraft in a science fiction setting. Science fiction was selected as the genre, as it requires a diverse range of sonic outputs and as it is a fictional setting, there should be less preconception of how it should sound. Spacecraft were chosen as over the years there have been many depictions of different types of spaceships: motherships, fighters, cargo freighters, shuttles, etc., which require different sonic identities, not only based on their type, but also to fit the narrative and aesthetic context. For example, the sound of the Nostromo[1] from the film Alien (1979) [16], sounds very different to the Millennium Falcon[2] from the film Star Wars: Episode IV - A New Hope (1977) [17], although they are both spacecraft depicted within a couple of years of each other. Having decided on the type of sounds, the different characteristics of each task were established. Six different goals were mapped to the six different interpolator interfaces. These were chosen to be as varied as possible so that each scenario was distinct:

Interpolator 1 - Soothing and healing sound for a medical hospital spaceship

Interpolator 2 - Manic and chaotic sound for a spaceship owned by a psychopath

Interpolator 3 - Calm and tranquil sound for a spaceship owned by a battle hero

Interpolator 4 - Threatening and scary sound for a spaceship where a killer is hunting the crew members

Interpolator 5 - Despair and despondency for the sound of a spacecraft that is stranded in deep space with no engines and dwindling life-support systems

Interpolator 6 - Sombre and gloomy sound for a dying spaceship that is being eaten by parasitic space slime

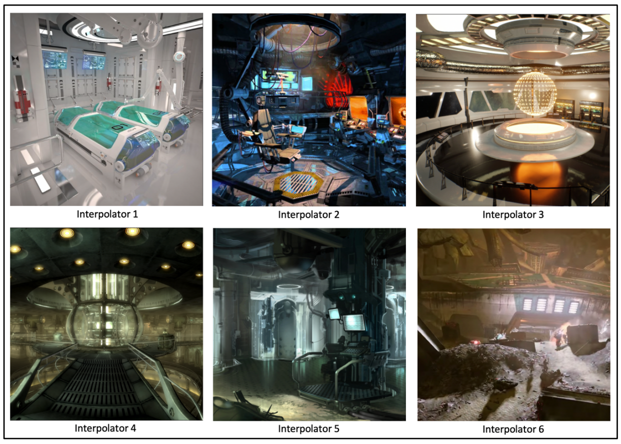

Figure 4 Visual Representations for the Tasks

To provide some focus for each scenario a visual representation (Figure 4) was supplied on an informative basis to give the participants a particular target aesthetic and make the sound design task as concrete as possible. These provided some similarity in the nature of the tasks but suggested unique sonic solutions for each of the allocated interpolators. The same ten preset sounds were set up in

[1] Recording of the Nostromo Ambient Engine Noise https://youtu.be/U4p1mZnKkhc

[2] Recording of the Millennium Falcon Ambient Engine Sound https://youtu.be/P93kbL0G0ww

each interpolator, at identical fixed locations that could not be modified by the participants. These provided a diverse range of spacecraft ambience sounds.

The participants were presented with the sound design tasks and associated interpolators in a random order. Before the experiment was started participants were given the opportunity to complete an interpolator training session, where they were introduced to interpolator functionality and operation. To avoid showing them any of the interfaces being used in the experiment, an interface was used that only showed the preset handles and had no other visual cues. The participants were given the written scenario and the corresponding visual representation, and they were then free to initiate the test once happy that they understood the sound design requirements. The interpolator/scenario allocations were the same for each participant so that comparisons could be made between them. All other aspects of the interpolation system – inputs, interpolation calculations, mappings (all parameters) and synthesis engine (Native Instruments' Massive) – remained identical between the six interfaces. As a result, sonic differences between the interpolator outputs were purely a function of the different visual models. Each test lasted a maximum of ten minutes with the participants being able to stop the test beforehand if they chose. When the participants felt that they had achieved the sound design goal, they pressed a "Target" button to register the location.

5. RESULTS

The desired number of participants for the experiment was set at thirty-six, based on a power assumption of 0.8 and the desire to observe a medium effect size (0.1758631) [18]. However, due to Covid-19 restrictions the number of participants was limited to twenty. All the participants recruited had some degree of sound design experience and all their interactions with the interfaces were captured via the recording of mouse movements. This allowed traces of the movements to be visually compared between the different interfaces. The trace gives a pictorial representation of the journey that each user made through the interpolation space. An example is shown in Figure 5.

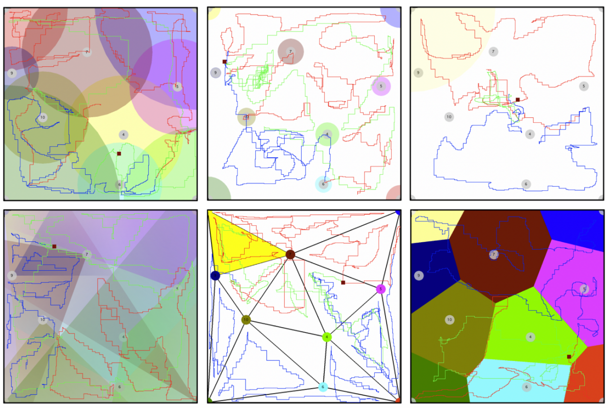

Figure 5 Mouse Traces for Participant 1 - Showing Top Row Interface 1 – 3 and Bottom Row Interface 4 – 6 and the Participant's Chosen Location (■)

To aid interpretation, the traces have been coloured so the first third of the trace is red, the next third blue and the final third green. On inspection it was found that participants appeared to follow the previously observed trend of three distinct phases of interpolation: *exploration* through making large fast moves through the space, *localisation* on region-of-interest, but occasionally checking if better options exist and *refinement* through slow small movements in the space [8]. These can also be seen by viewing a plot of cursor speed over the duration of the test. Figure 6 shows this for participant 3 in the first test they took.

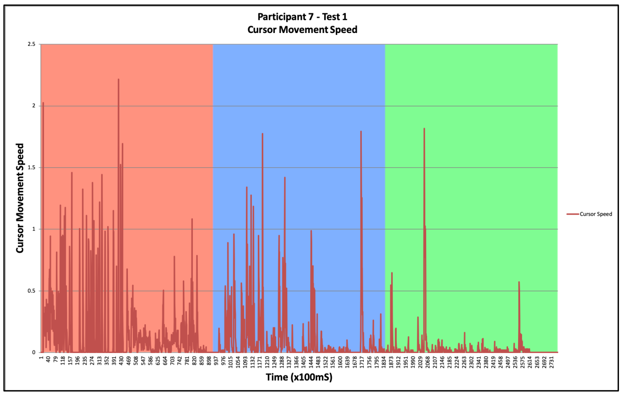

Figure 6 Mouse Speed - Sampled Every 100mS for Participant 7 with Interface 5

Although these phases do not always split evenly into thirds of the task time, many of the participants appear to follow this trend. In addition, it was noted from the traces that sometimes confirmatory moves are made in the refinement phase and slower moves are sometimes made in the exploration phase when interesting results were found. As can be seen in this plot during the first phase this participant did find an area that caused their movements to slow so that smaller distances were travelled. Also, during the final refinement phase, some faster moves were made, as normally seen when localising on regions of interest

Despite these anomalies the three phases of spatial interpolation appear to hold providing further evidence of this search behaviour being common to interpolators. It should also be noted that some participants would exhibit different *modus operandi*. For example, (Figure 7) participant 13 adopted a strategy where they undertook their navigation of the space and then afterwards, they clicked on different locations, causing the cursor to jump and audition the sound at alternative positions.

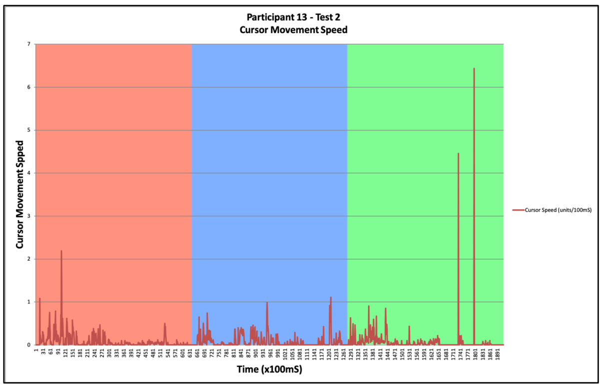

Figure 7 Mouse Speed - Sampled Every 100mS for Participant 13 with Interface 3

This example is shown for interface 3, but the participant followed the same strategy, to a greater or lesser extent, with each interface. However, aside from these cursor jumps, this participant still appeared to search the space in a similar manner. This indicates that some users have unique navigational strategies that they use across the interpolator interfaces, regardless of their graphics.

To statistically confirm the presence of the phases that have been observed here and previously [8], the mean speed of cursor movement and mean number of high-speed moves were calculated for each phase across all tests. Note that a high-speed move was defined as greater than 0.5 units/100mS. This value was chosen as it represents moving half the unit squares distance in the sample time which shows as medium spikes on the mouse speed plot (Figure 6). The results of these calculations show that both the mean cursor speed and number of high-speed moves decrease at each stage (Table 1).

Phase	Mean Cursor Speed (Standard Deviation)	Mean High-Speed Moves (Standard Deviation)
Exploration	1.373 units/sec (SD = 0.607)	40.28 mvs (SD = 38.76)
Localisation	0.981units/sec (SD = 0.433)	23.94 mvs (SD = 17.04)
Refinement	0.565 units/sec (SD = 0.422)	13.62 mvs (SD = 14.92)

Table 1 Mean Cursor Speed and Number of High-Speed Moves for the Three Phases of Interpolation

Null Hypothesis Significance Testing (NHST) was undertaken to establish if the differences between the phases were significant. It was hypothesized that during the first phase (exploration) the participants would have a higher average cursor movement speed and make more high-speed moves. These would then both reduce during the second phase (localisation) and then again during the final refinement phase (H_A: $Median_1 > Median_2 > Median_3$). Non-parametric methods were used due to the non-normal distribution of the data and the effect size was calculated using both correlation coefficient (r) [19] and probability score depth (*PSDep*) [20]. Friedman tests showed there were statistically significant differences between the phases for the average cursor speed ($\chi^2(2) = 120.5167$, $p < 0.001$) and the number of high-speed moves ($\chi^2(2) = 82.5489$, $p < 0.001$).

As a result, post-hoc pairwise Wilcoxon tests were undertaken with a Bonferroni correction which showed there are significant differences in how the users interact with the interfaces during each of the different phases of the interpolation. Using normal conventions [21], it indicates medium to large effect sizes. The results are summarised in Table 2.

Variable	Wilcoxon	Sig	r	PS_{Dep}
Speed	Z = -6.408	p < 0.001	-0.414	0.742
	Z = -8.771	p < 0.001	-0.566	0.917
	Z = -7.466	p < 0.001	-0.482	0.833
High-Speed Moves	Z = -5.256	p < 0.001	-0.339	0.667
	Z = -7.772	p < 0.001	-0.502	0.85
	Z = -6.079	p < 0.001	-0.392	0.742

Table 2 Significance Testing of Interpolation Phases for Mouse Speed and Number of High-Speed Moves

As with the previous study [8], NHST was undertaken on the mouse data to establish if there were differences between the interfaces for user interactions. Friedman tests were undertaken for the total cursor movement time, average cursor speed and the total distance the cursor moved. In all three cases the results showed no significant difference between the interfaces (Time - $\chi^2(5) = 4.886$ and $p = 0.430$; Speed - $\chi^2(5) = 6.714$ and $p = 0.243$; Distance $\chi^2(5) = 4.429$ and $p = 0.489$). Although the interfaces provide different visual cues, in these tests there is no evidence they had an impact on the participants' interactions.

The same method was used to compare the distance to the mean selected location for each interface, to determine if the distribution of selected locations could be related to the interface's visual cues. The results showed a statistically significant difference exists between the interfaces, $\chi^2(5) = 20.114$, $p < 0.001$. The post-hoc (pairwise Wilcoxon signed-rank tests with a Bonferroni correction) showed only one statistically significant difference between Interface 1 ($Median_1 = 0.319$ units, IQR = 0.400 units – 0.231 units) and Interface 6 ($Median_6 = 0.534$ units, IQR = 0.597 units – 0.399 units), Z = -2.949, $p < 0.0032$). The effect sizes ($r = -0.466$, $PS_{Dep} = 0.75$) showed a medium effect.

To further understand these results, the mean standard distance deviation was calculated to compare how much of the interpolation space was explored with each interface. This is based on the unit square size of the interfaces and are shown in Table 3.

	Mean Standard Distance Deviation (Standard Deviation)
Interface 1	0.397 units (SD = 0.051)
Interface 2	0.387 units (SD = 0.042)
Interface 3	0.412 units (SD = 0.053)
Interface 4	0.380 units (SD = 0.057)
Interface 5	0.434 units (SD = 0.067)
Interface 6	0.467 units (SD = 0.066)

Table 3 Mean Standard Distance Deviation by Interface

As can be seen, all the interfaces in this experiment resulted in higher means than those generated in the previous study [8], including the one common interface (nodes). This maybe the result of this experiment having a different goal for the participants, as in the previous study all the participants were asked to locate a single target sound with the interpolators. It is noted that the two interfaces that the dimension space analysis showed as providing the most detailed visual cues, tessellation (Interpolator 6) and triangulation (Interpolator 5), achieved the two highest scores for the standard distance deviation. Similarly, the one with the lowest standard distance deviation, light (Interpolator 4) was an interface that the dimension space analysis showed to provide less detail. This reveals that in this experiment the interface's that possess more detailed visual cues resulted in navigation of a larger area of the space.

The locations the participant selected as their chosen sounds were also plotted to see if there were trends resulting from the different interfaces. Figure 8 shows the selected sound locations for all the participants, by interface.

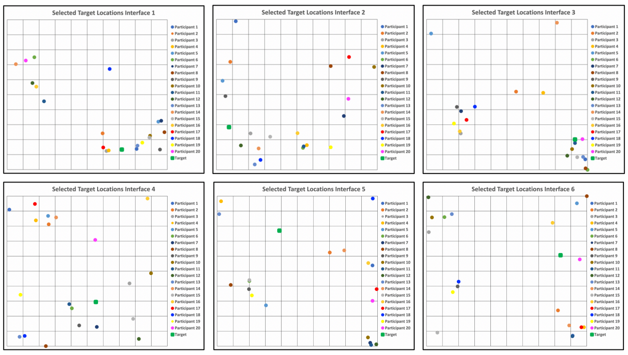

Figure 8 Participants Selected Target Locations by Interface and the Location of the Target Sound (■)

Given the subjective nature of the sound design task it is no surprise that it resulted in a wide distribution of selected locations. Nonetheless, from inspection it appears that there is some clustering of selected locations within the space. This may indicate that despite the subjective nature of sound design, there are common sonic traits that the participants identified for each scenario. From the results shown in Figure 8 the standard distance deviation was calculated with respect to the mean selected location, again based on the interfaces unit square. Hence this provides a basic measure for the distribution of selected locations (Table 4).

	Standard Distance Deviation
Interface 1	0.385 units
Interface 2	0.394 units
Interface 3	0.437 units
Interface 4	0.441 units
Interface 5	0.488 units
Interface 6	0.523 units

Table 4 Standard Distance Deviation of Selected Locations by Interface

It was noted that from these values there is again an apparent correlation with the dimension space analysis. Interface 1 had the lowest distribution of selected locations (Table 4) and, as shown in Table 3, the participants also explored less of the space. The dimension space analysis showed this interface to provide fewer visual cues in contrast to Interfaces 6 and 5 which both offer more detailed cues and resulted in users exploring more of the interpolation space and a wider distribution of selected locations.

6. DISCUSSION

From examining the mouse traces and selected locations for each interface, there is a correlation between those the dimension space analysis showed as providing more detailed visual cues, and the ones that resulted in larger distances being covered. Although this fits with what was discovered in the previous study [8], it was not possible to show a significant difference between the interfaces for time, speed and distance. Where significance was shown for the distribution of selected locations, it was only shown for one case. These results appear to indicate that although the interfaces present the users with different visual cues, these do not appear to affect the user performance when undertaking a sound design task with the interface. This might have been impacted by the number of participants recruited or from natural variation given that a confidence interval of 0.95 was used. Another potential factor might have been the fixed layout of the presets which could have been restrictive and limited exploration, especially given that experienced participants were deliberately recruited.

In this testing it has been possible to show again the presence of three interpolation phases (exploration, localisation and refinement). These had been previously observed, albeit with a limited range of interfaces [8]. However, it has now been possible to show that the phases are present for a much wider range of different interpolation interfaces. In addition, it has now been possible to show significant differences between the phases for the speed of cursor movements and the number of high-speed moves. This gives further confidence that the effect observed in the previous study is genuine and present regardless of the visual cues presented to the user. However, given that the visual cues for each interface were static and did not change during the experiment it seems that an Interactive Visualization (IV) paradigm could be of further benefit by allowing the user to change the level of visual detail on the interface during the different phases. Moreover, given that as the user gets closer to their intended location, they tend to make smaller moves and travel less distance, some form of zoom function could be advantageous to provide a finer level of control for the user, allowing more detailed sound design to be undertaken. Such an interface approach has already been shown to benefit an exploration process [22].

7. CONCLUSIONS

Given the number of participants in this study, care is required when interpreting the results. In the future, it will perhaps be possible to continue this study with more participants which may deliver a clearer view of any trends and provide greater confidence in the results. Nonetheless, the results appear to indicate that the more visual cues the graphical interpolation interface has, the wider the exploration of the space undertaken.

It should be noted that this experiment only examined the process of interpolator navigation and so all other attributes were controlled and unchangeable by the participants (preset sounds, locations, field-of-influence, etc.). As a result, the experiment results only capture a part of the overall usability of these tools and if the users were given a greater range of controls, potentially it will further affect the results. Future experiments will look to assess the impact that these additional controls provide.

It has now been shown that there is a significant difference in the user's interaction during the three phases of interpolation, regardless of the interface used. This suggests that the affect is from the process of interpolator navigation, rather than being dependent on the interface presented. It may be that this phenomenon is a result of any spatial navigation/exploration process and not unique to interpolation. In which case, the results may be applicable to many other areas where spatial searching is undertaken. Based on these findings, future work should consider the design of interfaces that provide users with visuals that facilitate the different phases of interpolation. In addition, it is suggested that the visuals should not remain static, but should be user controllable, either allowing them to directly control the selection of different visualisations or automatically based on their interactions with the space. It is also noted that in the experiment results for the interpolation phases, the total test time was divided evenly into three. This appeared to work for many of the participants and provided a quick and easy way to identify differences in the user's interactions during the test time. However, it was seen that not all participant's interactions split evenly into thirds of the test's time and some participants appeared to move between the different phases of interpolation at different points in the process. Using a more data driven approach to define the phases, such as using the cursor speed, frequency of high-speed moves or distance moved against averages, could provide more accurate results. Given that the datasets from both experiments are available this is further analysis that will be undertaken. The results may then be used to automatically detect the phases from user interactions so the visualisation could be adapted depending on which interpolation phase the users are in.

The dimension space analysis provided a good guide for evaluating interpolator visual cues and so could be used or refined in subsequent interpolator developments to gauge the potential usability of different interface designs.

8. REFERENCES

[1] D. Gibson and R. Polfreman, "A framework for the development and evaluation of graphical interpolation for synthesizer parameter mappings," presented at the Sound & Music Computing Conference 2019, Malaga, Spain, 2019. [Online]. Available: http://eprints.bournemouth.ac.uk/32726/.

[2] "nodes. Max Reference.," ed. Cycling 74, 2016.

[3] J. F. Allouis, "The SYTER project: Sound processor design and software overview," presented at the In Proceedings of the 1982 International Computer Music Conference (ICMC), 1982, 232–240.

[4] D. Shepard, "A two-dimensional interpolation function for irregularly-spaced data," presented at the Proceedings of the 1968 23rd ACM national conference, 1968.

[5] M. Spain and R. Polfreman, "Interpolator: a two-dimensional graphical interpolation system for the simultaneous control of digital signal processing parameters," *Organised Sound,* vol. 6, no. 2, pp. 147-151, 2001.

[6] K. Adiloglu, C. Drioli, P. Polotti, D. Rocchesso, and S. Delle Monache, "Physics-based spike-guided tools for sound design," presented at the Conference on Digital Audio Effects, 2010.

[7] R. Bencina, "The metasurface: applying natural neighbour interpolation to two-to-many mapping," presented at the Proceedings of the 2005 conference on New interfaces for musical expression, 2005.

[8] D. Gibson and R. Polfreman, "Analyzing journeys in sound: usability of graphical interpolators for sound design," *Personal and Ubiquitous Computing,* vol. 25, no. 4, pp. 663-676, 2021/08/01 2021, doi: 10.1007/s00779-020-01398-z.

[9] D. Gibson and R. Polfreman, "Star Interpolator - A Novel Visualization Paradigm for Graphical Interpolators," presented at the In: NIME2020: New Interfaces for Musical Expression, 21- 25 July 2020, Royal Birmingham Conservatoire, Birmingham, UK., 2020. [Online]. Available: http://eprints.bournemouth.ac.uk/34005/.

[10] D. Birnbaum, R. Fiebrink, J. Malloch, and M. M. Wanderley, "Towards a dimension space for musical devices," in *Proceedings of the 2005 conference on New interfaces for musical expression*, 2005: National University of Singapore, pp. 192-195.

[11] T. Magnusson, "An Epistemic Dimension Space for Musical Devices," in *International Conference on New Interfaces for Musical Expression (NIME)*, 2010, pp. 43-46.

[12] O. Larkin, "INT.LIB–A Graphical Preset Interpolator For Max MSP," presented at the ICMC'07: Proc. of the 2007 International Computer Music Conf, 2007.

[13] J. J. van Wijk and C. van Overveld, "Preset based interaction with high dimensional parameter spaces," *Kluwer international series in engineering and computer science,* pp. 391-406, 2003.

[14] D.-T. Lee and B. J. Schachter, "Two algorithms for constructing a Delaunay triangulation," *International Journal of Computer & Information Sciences,* vol. 9, no. 3, pp. 219-242, 1980.

[15] M. Wójcik-Augustyniak, "How to measure and compare the value of organizations. The case study of HEIs," *Entrepreneurship and Sustainability Issues,* vol. 7, no. 3, pp. 2144-2169, 2020.

[16] G. Nis, "The Sound of Horror - Silence & Sound Contrasts in Sci-Fi Horror Movies," *Journal of Media, Cognition and Communication,* vol. 1, no. 1, 06/10 2013.

[17] G. Sergi, "Tales of the Silent Blast: Star Wars and Sound," *Journal of Popular Film and Television,* vol. 26, no. 1, pp. 12-22, 1998.

[18] D. Lakens, "Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs," *Frontiers in psychology,* vol. 4, p. 863, 2013.

[19] R. Rosenthal, "Parametric measures of effect size," in *The handbook of research synthesis*, vol. 621, 1994, pp. 231-244.

[20] R. J. Grissom and J. J. Kim, *Effect sizes for research: Univariate and multivariate applications*. Routledge, 2012.

[21] J. Cohen, *Statistical power analysis for the behavioral sciences 2nd edn*. Erlbaum Associates, Hillsdale, 1988.

[22] R. Tubb and S. Dixon, "The Divergent Interface: Supporting Creative Exploration of Parameter Spaces," presented at the In International Conference on New Interfaces for Musical Expression (NIME), 2014.