NEW ZEALAND TEACHERS' PERCEPTIONS WHEN HEARING WAITING-TIME DISTRIBUTIONS

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The use of sounds to explore statistical concepts is a novel approach, not yet fully explored. The purpose of this paper is to consider the feasibility of using sounds to represent waiting-time distributions. As a potentially advantageous element of a prototype statistical learning tool, we endeavour to determine if relating sounds to distributions is valuable. Extending on pilot study findings, preliminary data collected from an online anonymous questionnaire sent to New Zealand secondary school teachers is presented. Results show that the majority of teachers who responded to the questionnaire selected the correct distribution. This suggests that the use of sounds to represent waiting-time distributions may be a beneficial component of the statistical learning tool that challenges participants to apply their understanding of distributions in new ways. This might grow to be a new skill in a changing world, as a previously unexplored use of technology and the auditory capabilities it provides.

BACKGROUND

Within statistics, it is commonplace to use visualisations for teaching. However, we wondered whether including additional alternative senses could be activated to enhance reflection on the properties of distributions. This exploration originated from a pilot study using a statistical learning tool that featured sounds as an additional way to experience waiting-time distributions (Renelle et al., 2019). Exploration into the use of sounds is still at its infancy, with limited literature considering the benefits and barriers to this. In further investigating a novel approach to reflecting on properties of distributions, it was thought that considering teachers' ability to translate sounds into distributions would be an appropriate place to start. In this paper, data collected via an online anonymous questionnaire sent to New Zealand secondary school teachers is considered.

In New Zealand, known distributions (or "named/statistical" distributions) are introduced to senior secondary school students aged 16 to 18 years old (NZ Ministry of Education, 2007). In particular, classroom content typically focuses on the binomial, normal, Poisson, uniform, and triangular distributions. However, relating random events to known distributions is not a major focus in many New Zealand statistics textbooks (for example, in Barton & Laverty, 2013) and is a potential area of misunderstanding for students (Engel & Sedlmeier, 2005). The disconnect between randomness and distributions may result in students failing to see how distributions are accumulated from individual events. Similarly, students may also have difficulty understanding the reverse; that is, how simulations draw random values from distributions (Arnold & Pfannkuch, 2010). It may be the case that the use of sounds as individual events could be used to present an alternative experience of distributions and randomness.

Engel and Sedlmeier (2005) commented that the disconnect between individual outcomes and a global perspective is not uncommon with students. As an example of using a visual task to relate individual events to an accumulative picture, Engel and Sedlmeier (2005) used a snowflake example from Piaget and Inhelder (1974) as a real-world situation to help participants (middle-school students) relate randomness to a previous experience. This task challenged the disconnect between real-world experiences and statistical teachings. Further, the task brought students' attention to the relationship between singular events and the global picture, relating individual outcomes (snowflakes) to distributions (uniform distribution).

While Engel and Sedlmeier (2005) reference students, a search of the literature failed to uncover studies based on teachers' perceptions of randomness and distributions. Therefore, we felt that it was appropriate to first explore whether teachers, who should be familiar with the properties of distributions, can listen to a sound sequence and correctly determine the underlying waiting-time distribution that generated those sounds. In doing this, we attempt to consider the feasibility of using sounds to create a novel learning experience. We suggest that, if teachers are mostly able to identify a distribution from a sound sequence, it may be reasonable to expect students to be able to discuss and explore distributional properties through sounds.

Multisensory learning in statistics could provide new experiences for students to engage in statistical concepts (i.e. Richardson et al., 2008). With the use of multisensory learning shown to be advantageous (i.e. Mitchel & Weiss, 2011; Richardson et al., 2008; Shams & Seitz, 2008; Slobodenyuk et al., 2015), the use of auditory cues may provide a new environment in which understanding of the connection between random events and known distributions may be possible.

Our research question is hence: How feasible is the use of auditory cues as a potential avenue to assist in developing students' understanding of waiting time distributions?

METHODOLOGY

Participants

With the aid of several New Zealand mathematics associations, particularly the New Zealand Association of Mathematics Teachers (NZAMT), we sent New Zealand secondary school teachers an invitation to participate in an online, anonymous questionnaire. There were 153 responses. 48.4% of participants were male and 51% were female, with 0.6% identifying as gender diverse. The majority of participants taught both mathematics and statistics (78%) and taught at a range of year levels.

Questionnaire

The exploratory question considered in this paper is as follows (Figure 1), with the accompanying audio clip which can be heard here: https://tinyurl.com/yzoerska. The question asks participants to listen to an audio clip and then decide if the waiting time between sounds is best represented by the exponential distribution or the uniform distribution. The correct answer was the uniform distribution, as depicted in the first option of the answers to the question (Figure 1).

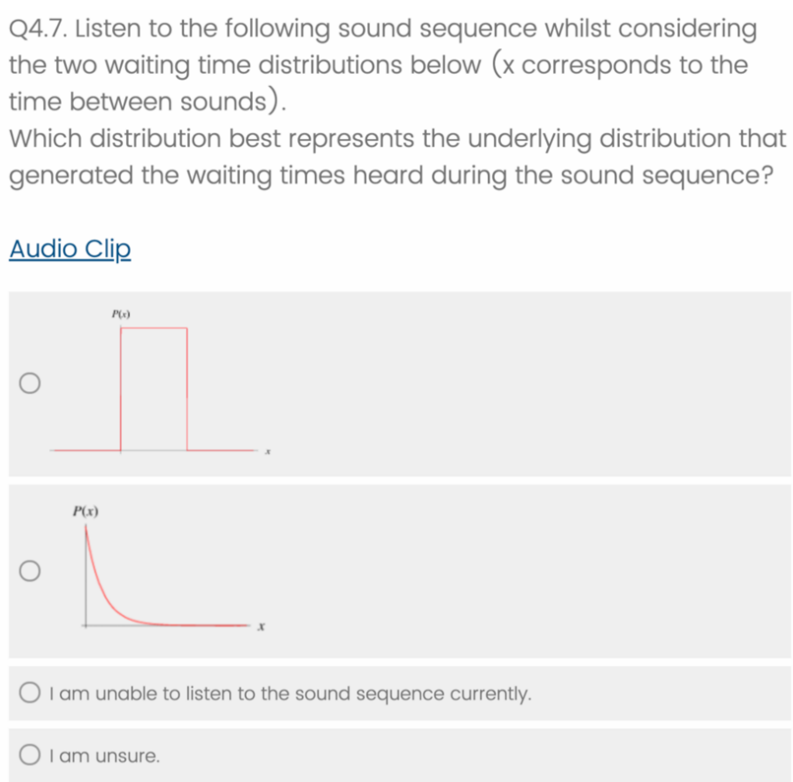

Figure 1. Screenshot of the corresponding question from the online, anonymous questionnaire

RESULTS

As seen in Figure 2 (below), a large proportion of teachers who responded to the questionnaire correctly determined that the waiting times heard in the sound sequence were generated from the uniform distribution. Almost 20% of participants were unsure, and another 20% decided the sound sequence was generated from the exponential distribution. If we remove the responses from participants who were unable to listen to the sound sequence (20%), we see that the majority of those who listened to the sound sequence chose the uniform distribution as their answer (55.6%), significantly more than we might expect by chance. Further research, yet to be conducted, could clarify the underlying reasoning for participants' choices.

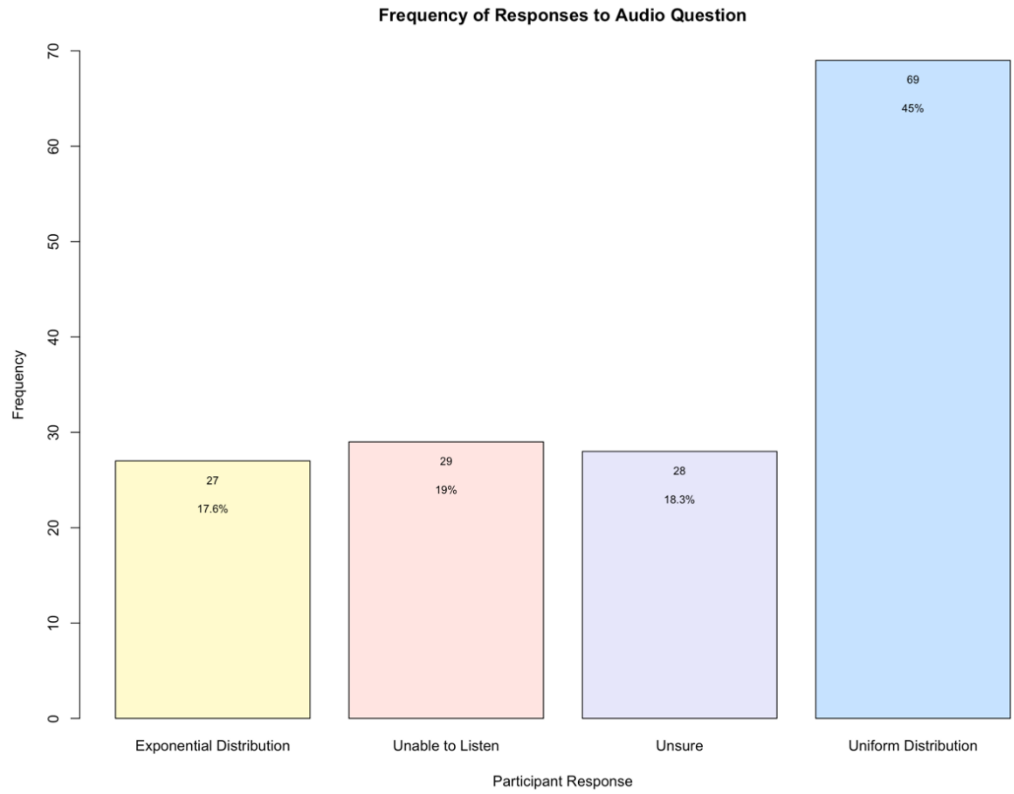

Figure 2. Frequency of responses to the audio question (shown in Figure 1)

These initial results suggest that the use of sounds to represent distributions may be beneficial. That is, distributions may be identifiable from sound sequences. Indeed, as a unique way of considering waiting-time distributions, the use of sounds may generate comprehensive discussion around the properties of waiting-time distributions. These kinds of discussions could highlight properties of distributions; for example, in the case of the uniform distribution, the use of sounds and discussion around this could emphasise that there is more than one waiting time (i.e. one second, two seconds, three seconds) but they occur approximately as often as each other.

As an example of this from a pilot study (Renelle et al., 2019), when a similar question was tested with university students, the participants anticipated a constant "metronome" sequence of sound when simulating from the uniform distribution. In hearing the sound sequence (which did *not* sound like a metronome), there was then an opportunity to compare between distributions (in this case, simulating constant waiting times, which *did* sound like a metronome) and discuss why the participants' prediction was incorrect. During this pilot study, the sounds were generated using a new tool, called the *Scampy Tool*, developed at the University of Auckland that aims to help students experience randomness, and to make connections between waiting-time distributions (Budgett & Pfannkuch, 2018). As an extension from this pilot study, the questionnaire to teachers aimed to further examine the feasibility of using sounds to convey distributional properties The results from the questionnaire (Figure 2) indicate that this feature of the *Scampy Tool* may be a beneficial component. Further research is needed in order to explore the benefits and barriers to relating sounds and distributions.

IMPLICATIONS FOR TEACHING

This paper examined the feasibility of incorporating auditory cues in statistical learning tools. With technology becoming increasingly common in classrooms, novel approaches – such as the integration of an auditory component – may provide a new way of experiencing key statistical concepts. The results from the questionnaire considered here indicate that there is the potential for connections between a sound sequence and its corresponding waiting-time distribution to be made. The purpose of this study was to carry out a preliminary investigation into whether teachers, who should be familiar with distributional properties, can correctly identify the underlying waiting-time distribution that generated the sound sequence. The results from this study indicate that the use of sounds in a statistical learning tool may be beneficial, and it is speculated that the use of sounds would be particularly beneficial if accompanied by a discussion of the properties of waiting-time distributions. Through discussion of how the sounds are generated by the statistical learning tool, it is anticipated that students would have the opportunity to reflect on the properties of waiting-time distributions, and on the connection between random events and distributions in a new and engaging way. However, the results from this study should be interpreted with caution. The respondents to the questionnaire were self-selected, so the findings are not necessarily generalizable. Furthermore, there were only two distributions for the participants to select from. Further research could explore whether performance was as good when options included more possible distributions to choose from. Also, as there is limited literature investigating the benefits and barriers of using sound in relation to distributions, further research is necessary to determine if classroom implementation is both possible and advantageous. As a potential enhancement to statistical learning tools, the use of sounds to represent waiting-time distributions needs to be further explored. In particular, future studies will consider the ways in which the use of sounds can be implemented and how best to deepen students' knowledge of statistical distributions.

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