# Northern Arapaho virtual reality linguistic elicitation

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## ABSTRACT

Arapaho is an endangered Native American language with fewer than 100 fluent speakers, all elderly. The age and health of the speakers limits our ability to do traditional on-the-ground documentation of language in relation to geography and space. In this project, a virtual reality (VR) elicitation process was developed in collaboration with elders of the Northern Arapaho Language and Culture Commission. This new place-sensitive method of linguistic documentation uses aerial drone video and 8K resolution, three-dimensional (3D), 360-degree panoramas to visually and auditorily immerse elder consultants in physical locations oriented around the traditional Arapaho worldview. This method virtually transports elder speakers of Indigenous languages into places and contexts that may be physically impossible for them to visit in person, allowing them to recall place-based cultural and ecological knowledge. Analysis of interview data resulting from VR elicitation shows it to be comparable to other language documentation techniques in terms of the quality of the data while also possessing unique attributes and utility.

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# 1. INTRODUCTION

A spring wind ran her warm fingers through the short grass prairie plains of *Heneeceibooo* 'the buffalo trail'.[1] In the nearby town of Laramie, or *Niitokooxeeetiini'* (which means 'where we get tipi poles' in Arapaho), inside the modern red sandstone building of *Touhooniiteen* at the University of Wyoming (UWYO), a hushed and expectant silence settled over the small group of elders, family, students, and project staff. *Nii'eihii Neecee*, the culture bearer of the Northern Arapaho tribe whose name means 'Eagle Chief', began a virtual reality elicitation session by donning goggles and starting to slowly explore the interior of a *niiinon*, the Arapaho 'tipi'. The tipi was filled with tools, cooking utensils, clothing, buffalo robes, and all the traditional necessities of pre-reservation Arapaho life. As described by Lowood (2021, paragraph 1), virtual reality (VR) is the

> use of computer modeling and simulation that enables a person to interact with an artificial three-dimensional (3-D visual or other sensory environment. VR applications immerse the user in a computer-generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn as goggles, headsets, gloves, or body suits.

Virtual reality elicitation, a new method of linguistic elicitation proposed in this article, uses aerial drone video, 360-degree panoramic photography, and 360-degree spatial audio to visually and auditorily immerse elder consultants in physical locations of cultural significance. This paper explores the VR elicitation method in the context of Northern Arapaho language documentation, arguing that it is a novel elicitation technique that is comparable to other techniques such as use of interviews and pictorial stimuli, while also being especially useful in specific situations and contexts of language endangerment and land loss involving elder speakers of Indigenous languages. As seen in Figure 1, a large screen on the back wall of the 3D CAVE (Cave Automatic Virtual Environment) projected what Nii'eihii Neecee saw for everyone present.
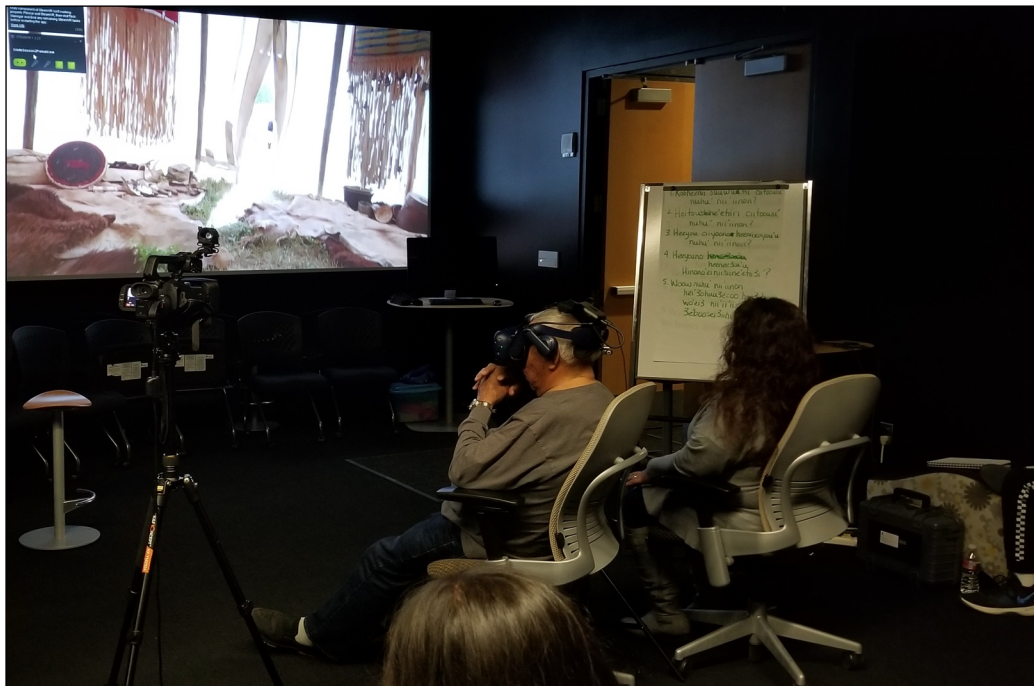


**Figure 1** Projection screen showing what Nii'ehii Neecee is seeing inside a niiinon in VR, 2019.

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[1]      We use the Standard Arapaho Orthography developed in the 1970s in this article. For a detailed description see Cowell and Moss (2011). The transcription used here for Arapaho speech uses a phonetic alphabet, and follows the conventions described at < https://verbs.colorado.edu/ArapahoLanguageProject/sounds/arapahosounds.html >. Note that Arapaho has a pitch accent system (similar to the stress system in English, except the pitch of the vowel is raised, rather than pronouncing the vowel with greater volume or intensity). Triple vowels are disyllabic with either a pronunciation *ée-é, íi-í, óo-ó* and *úu-ú* or else with a pronunciation *é-ee, í-ii, ó-oo, ú-uu*. The word 'road' is pronounced *bóoó*, while the word 'tipi' is pronounced *níinon*.

The niiinon serves as the Arapaho home and, through the process of entering and leaving it, a portal or cognitive bridge to other places and times. The niiinon also functions as a visual and symbolic marker of Arapaho ownership and occupation of their homelands far from the Wind River Indian Reservation. So, for example, after beginning his journey in the niiinon, Nii'eihii Neecee went on to explore Nohuuxone' and Biito'owu', Arapaho locations in Northern Colorado and Southern Wyoming, respectively. As a result of two years of iterative collaboration with elders and educators from the Northern Arapaho Language and Culture Commission, the VR linguistic elicitation method and the individual applications have been designed to include key components of both Arapaho language and culture. Some of the most prominent cultural elements are the Arapaho metaphors of center and periphery and the concept of the journey or path, literally movement from one physical location to another, but also more abstractly the symbolic or spiritual journey of life (Anderson 2008; Cowell 2018). The distinction between being *wotee-* 'to or at the center of the camp circle in the presence of other humans' and *nooo'-* 'away from center and human presence out in the prairie, hills and mountain peaks' is seen in the VR elicitation sessions and applications in that they always begin with elder Northern Arapaho speakers seated inside their traditional niiinon. Starting at the center of the home or camp circle and journeying out from there to accomplish daily tasks—and under special circumstances to seek the help of the living land and spirit world—is a process both familiar and sacred to the Arapaho (Anderson 2008). So each elicitation session begins inside the niiinon, which grounds the design of the VR elicitation applications within the traditional Arapaho worldview.

In this paper we discuss the VR elicitation method and its development, testing, and affordances. A diverse group of elder speakers participated in VR elicitation sessions in 2019 and 2020, and the audio recordings of these sessions were compared with the extensive corpus of Arapaho language at ELAR, the Endangered Languages Archive (Cowell 2014), in some cases with the same speaker and topic. The VR recordings and the non-VR recordings were interlinearized, annotated, and tokenized. They were then sorted computationally and analyzed statistically. The analysis showed that VR elicitation is comparable to other language documentation techniques such as pictorial stimulus, interviews, and the recording of spontaneous discourse. It has unique attributes in terms of capturing linguistic richness as evidenced in subordination and the use of transitive verbs, suggesting that elder speakers react to VR locations as if they were actually there. The comparison also showed that the movement from inside the niiinon out onto the land and back in interactive VR elicited rich connections between the niiinon, the environment, the general material culture of the Arapaho, and the key cultural values of respect and storytelling. It also elicited strong affective emotional and psychological responses from all the elders. The audio recordings of the VR elicitation sessions produced a strong sense of the niiinon as the nexus where human material culture and survival, landscape and environment, and human cognitive culture all coalesce. The unique stories and wisdom shared by the elders as they sat in the VR niiinon and moved out through the mountain passes and plains that were once theirs, but are now "wilderness" areas in state or national parks in Wyoming and Colorado, re-anchored them to those places. VR elicitation is valuable because it combines the traditional practices of storytelling within the niiinon and walking the land with the academic praxis of language elicitation. This article explores Northern Arapaho virtual reality elicitation with the hope that these new methods can be refined and extended to benefit other Indigenous language documentation efforts.

## 2. BACKGROUND AND CONTEXT

Andrew Cowell is a professor of linguistics who has done extensive research on Arapaho and is a proficient (though not native) speaker of the language. His role in this project has primarily been to transcribe and translate the Arapaho language data produced through the VR methodology and to assist in providing quantitative and qualitative analysis of that data. Phineas Kelly designed the VR methodology and engaged in the VR sessions and elicitation with the elders. The development of the VR elicitation method began in the summer of 2017, when Kelly brought the idea for a mobile place-based language and culture learning game for Arapaho to Dr. Christopher Russell, director of the University of Wyoming (UWYO) Native American and Indigenous Studies

department. Excited by the potential of the project, Dr. Russell and Robyn Lopez, the UWYO Arapaho Language Instructor, introduced Kelly to the elders of the Northern Arapaho Language and Culture Commission. Conversations with Northern Arapaho elders at the Arapaho Language Immersion school during language revitalization fieldwork that summer made one thing painfully clear: consumption of video games, the internet, and western media productions—all in English and now available to Arapaho youth 24 hours a day beginning in early childhood—is having a devastating effect on the transmission of the Arapaho language. Even families lucky enough to have fluent speakers at home were struggling to pass on the language and maintain the interest of young family members in the culture. A question emerged from our conversations: How can we use the tools and technologies of the western media entertainment machine that are facilitating the erasure of our language and culture to help save it? The first tangible step on the journey to find an answer to that question was the creation of an augmented reality mobile place-based game that teaches Arapaho language and culture. The game is currently being used by a diverse group of Native American high school students, as well as undergraduate and graduate students at UWYO (Kelly 2020). Feedback from the elders and language learners has led us to conclude that, in the words of Arapaho Elder Woo'uh'ei, "A game to teach our language and culture can be a way to fight the fire of Western media technology which is erasing us with fire!" (personal communication, 2018-07-17). These first steps led us to ask what other tools and technologies might be used to push back in some small way against the digital tsunami of English language media and entertainment. Besides the smartphones that are never far from the hands of Arapaho youth, arguably the most compelling media technologies are video games and movies, the newest and most addictive of which are in immersive 3D and VR. How can these specific technologies be used in new ways? These questions evolved into a proposal to the National Science Foundation Documenting Endangered Languages Program for which Andrew Cowell agreed to be the Arapaho linguistic consultant.

## 3. LANGUAGE OVERVIEW

Arapaho is an Algonquian language with two dialects, one of which is still spoken only in the western United States. Northern Arapaho is spoken on the Wind River Indian Reservation in Wyoming by fewer than 100 native speakers who are in their sixties or older, while there are no remaining fluent speakers of Southern Arapaho, which was spoken in Oklahoma (Cowell & Moss 2011). After the discovery of gold near Denver in 1858, European American settlers poured into the front range of Colorado, displacing the Indigenous Arapaho Tribe with violence and genocide, culminating in the infamous Sand Creek massacre of 1864. In 1878, the Northern Arapaho were relocated to the area of Wyoming that is now the Wind River Indian Reservation (see Figure 2). Since then, an array of sociological factors, from compulsory attendance at American Indian boarding schools whose aim was to forcibly eradicate Arapaho language and culture from Arapaho children up until 1978, to the continued predominance of English as the primary mode of instruction in K-12 education, to the inescapable influence of Western media culture, have all contributed to the current state of emergency for the Arapaho language.

Arapaho is a highly polysynthetic agglutinating language which packs vast amounts of information into morphologically complex verbs. This poses special challenges for the survival of the language in that, like other polysynthetic languages, the average number of hours it takes for an adult learner to become a proficient speaker can be as much as three to four times that of isolating languages, which neatly distinguish and separate constituents like subject, verb, and object (Green 2016). The Northern Arapaho are acutely aware of the critical state of their language and have been engaged in a variety of efforts to maintain it with both audio-recorded and written documentation and the development of language-teaching curricula. They developed now-standard Arapaho orthography in the 1970s. Extensive documentation of spoken Arapaho has been amassed by Cowell in the form of the Arapaho Conversational Database, deposited at the online Endangered Languages Archive (ELAR) linked to the Hans Rausing Endangered Language Documentation Programme; additional material has been collected since that initial deposit. More recently, Cowell's Arapaho Language
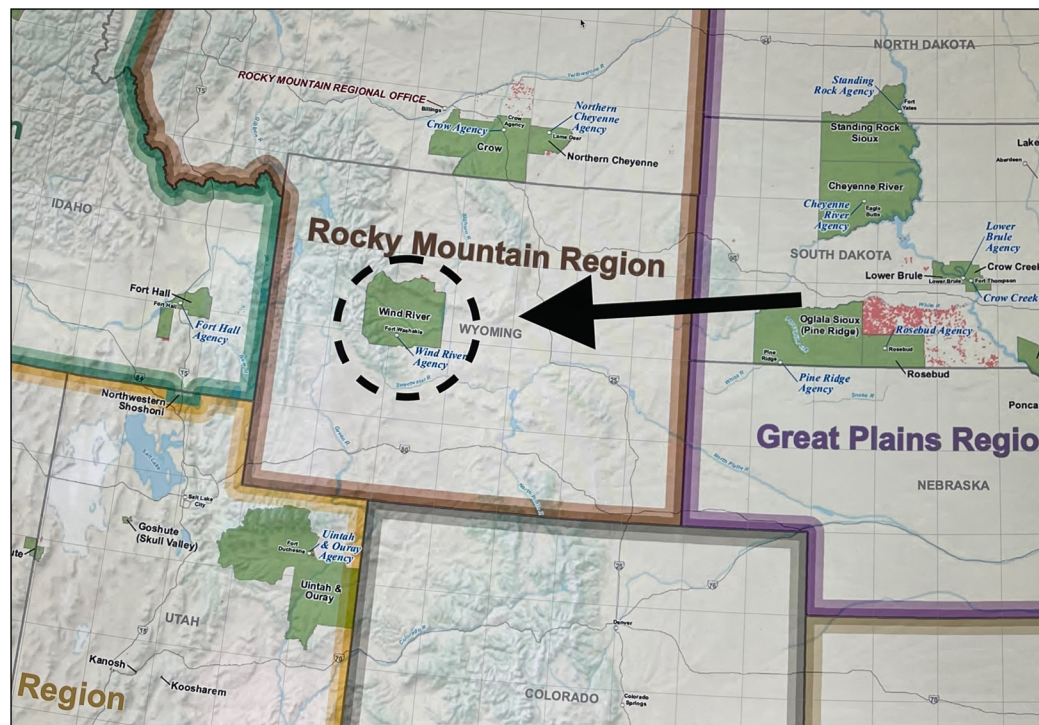
Project has made a variety of language teaching and learning materials available on the project website, and he has developed a lexical database with a morphological parser and concordancer (Kazeminejad et al. 2017), as well as a text database.[2]

## 4. VIRTUAL REALITY ELICITATION OVERVIEW

Virtual reality elicitation uses aerial drone video and 8K resolution, three-dimensional (3D), 360-degree panoramic photography (7,680 × 4,320 pixel photos captured with offset images to simulate the way that human eyes perceive depth) to visually and auditorily immerse elder consultants in physical locations of cultural significance. VR elicitation was developed in a two-year long process of iterative collaboration with the Northern Arapaho Language and Culture Commission in which versions of applications were shared and tested for both usability and cultural appropriateness. By virtually bringing elder speakers of Indigenous languages into places and contexts such as remote wilderness areas and private lands that are physically impossible for them to visit in person due to the physical limitations of age, lack of roads, or lack of permissions, VR elicitation allows speakers to apply autochthonous cultural and ecological knowledge to the land. When viewed in a VR headset, 8K 3D 360-degree panoramic photography and videography create a highly detailed and realistic ground-level visual experience that forms the basis for the immersive VR elicitation applications. Over the last year, the project has documented multiple locations on the Wind River Indian Reservation in southeast and south-central Wyoming and northern Colorado with previously documented and undocumented place names and/or places of special cultural significance to the Northern Arapaho. The locations of interest for the project were chosen specifically by members of the Northern Arapaho Language and Culture Commission who are all elder culture bearers and language keepers of the tribe. The specific locations and data were developed in collaboration with the UWYO Shell 3D Visualization Center into distinct VR elicitation applications built in Unity, a video game software development engine, for each location. The VR elicitation technique and technology presents elders with unique, compelling, and culturally meaningful multimedia experiences.

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2    The project website can be found at https://verbs.colorado.edu/ArapahoLanguageProject/index.html.

One of the key benefits of the VR elicitation method is that it is both a documentation and a revitalization tool: the elicitation applications—in which the elders view the locations of cultural significance and record spoken Arapaho about those places—become teaching and learning applications when the elder's speech is added to them. Traditional elicitation techniques, such as pictorial stimulus-driven elicitation and interview, are methods for eliciting and recording speech that must be turned into teaching and learning materials in a completely separate and time-consuming process that also requires distinct skill sets. VR elicitation applications are already teaching and learning applications about the locations of cultural significance they display, as the process of eliciting spoken language from elder speakers combines their knowledge with the place in a single process. The VR teaching and learning applications are the same as the VR elicitation applications, but with the spoken Arapaho of the elders added in so that language students view and move through the same locations in VR while they hear via the audio recordings and see in text callouts the words of the elders about those places.

The VR elicitation applications are built using the VR tools within the Unity video game development engine. While the platform is free (for non-commercial and small business creators), it takes considerable time and expertise to learn how to make anything in it. Basic knowledge of the C# programming language is needed, which presents a steep barrier to the utilization of VR as an elicitation technique by other communities and researchers. Understanding this from the beginning, a set of tools for VR elicitation and teaching and learning application development are being developed by Phineas Kelly and the UWYO Shell 3D Visualization center, which supports campus 3D data visualization, data capture, 3D asset creation, and software-development at the University of Wyoming. The tools and methods developed in this project will function as a stand-alone tool kit that can be used with only limited knowledge of computer programming or Unity itself. Content development for VR in this project and other similar applications entails the collection of 360-degree panoramic images of physical places. Luckily, 3D 360-degree cameras are now relatively inexpensive and easy to use, and they produce high quality images, mitigating yet another potential barrier to VR application development.

A key aspect of VR elicitation is the concept of presence, or the subjective impression and experience of being immersed in and enveloped by a virtual world rather than the real world in which the consultant is actually situated (Hale and Stanney 2014; Hillis 1999; Schuemie et al. 2001). The sense of presence creates the experience of being transported to another physical location which the viewer can examine in lifelike 3D 360-degree detail. VR elicitation as prototyped in this project is an improvement on traditional pictorial stimulus-driven elicitation techniques, which present consultants with pictures, line drawings, or video clips and ask them to describe what they see, because it envelops consultants completely in a lifelike world. VR elicitation utilizes high resolution 8K 3D panoramic photographs and video of actual physical environments in hyper-realistic 3D detail so that individual blades of grass on the ground look real, unlike traditional VR simulations that have the semblance of reality but appear flat and artificial in comparison.

360-degree panoramas have been shown to be the most valid display format for eliciting psychological response, and VR simulations have been shown to be the most effective display format for eliciting physiological response (Higuera-Trujillo et al. 2017). There is a vast difference between viewing a photograph or a two-dimensional video clip of a place, as in pictorial stimulus-driven elicitation, and experiencing it within immersive 8K (8000-pixel) 3D VR. 8K 3D virtual reality is so visually detailed and realistic that it has been demonstrated to have measurable psychological and physiological effects, such as reduced systolic blood pressure and heart rate as well as a decrease in reported negative emotions, which nearly replicate the actual experience of being in a specific outdoor location (Yu et al. 2018). Upon his first experience of a VR simulation, Nii'eihii Neecee exclaimed that it was like seeing *biiteino'* 'ghosts'. Both the niiinon itself and the locations of cultural significance that Nii'eihii Neecee visited when he made his remark are part of reservation and pre-reservation lived history that have been passed down only orally. So seeing—and as importantly *experiencing*—these storied places for the first time was profound.

In Arapaho and Native American ontology and worldview, land and landscape have always been placed at the center of cultural and religious life (Basso 1996; Deloria 2003). Use of VR elicitation methodology is part of a larger movement by Indigenous peoples and scholars around the world to use technology in ways that acknowledge this. One of the first and most prominent examples of this is the Digital Songlines Project, which employs immersive VR simulations to connect Australian Indigenous Peoples' art, stories, rituals, and songs with their land to reproduce aspects of the Dreamtime, the sacred origin of their worldview, stories, religion, and culture (Barrett 2013; Leavy 2007). Immersive VR has also been explored as a tool for traditional knowledge repatriation with Inuit elders with positive results (Dawson et al. 2011). Recent explorations of the potential of mapping and locative technologies to broaden research perspectives and allow consultants access to locations that would otherwise be physically inaccessible suggest that they have vast potential to broaden the field of linguistic research by creating new elicitation techniques with technologies heretofore unutilized (Berez 2015; Caldecott & Koch 2014; Hermes 2019; Lum & Schlossberg 2014; Mertins 2016). This new method of elicitation, material collection, and presentation has the foundational benefit of allowing the consultants to access landscapes in ways that were previously only available by plane or by visiting the location in person on the ground, a journey that a vast majority of elder Indigenous language consultants are physically unable to complete. An added benefit of using VR for elicitation purposes is that it may also be able to avoid some aspects of the observer's paradox in that the consultants can perceive themselves as visually and auditorily separated from the project team during the elicitation session.

## 5. METHODS OF DATA COLLECTION

Data was collected from both male and female speakers in individual and group elicitation sessions. Consultants were seated in swivel chairs to facilitate their exploration of the full 360-degree view shed and supported as they donned HTC Vive headsets. Once grounded in the first scene (always the interior of the niiinon), consultants were led through each scene of the virtual reality application. In each scene they responded to questions that Nookhoosei Niibei asked them in Arapaho about locations of cultural significance. They were also invited to converse with each other about toponyms and stories and to offer other descriptive information about what they were seeing and experiencing in virtual reality. Throughout the sessions, discourse and general responses to questions about locations of cultural significance were recorded using a Zoom F8n Multi-Track Field Recorder and a high-definition video camera. Data was backed up to portable hard drives on site and to cloud-based repositories when available.

For this project, symbolically and culturally significant locations in Rocky Mountain National Park were chosen by the Northern Arapaho Language and Culture Commission as the first targets of elicitation. These sites are connected to important themes in Arapaho myth, as they are related to the struggle between summer and winter, day and night, and the Thunderbird and the White Owls. Clearly VR elicitation is not preferable to visiting a location of cultural significance in person. But given that one of them, *Nohuuxone'* 'the eagle's nest', is located at 10,666 feet above sea level at the end of an arduous five-mile rocky climb, VR is the only chance that elderly Arapaho speakers will ever have of visiting Nohuuxone' or the other locations documented for this project again. Beyond its spatial utility, the VR elicitation prototype also allows elders move temporally back into the pre-reservation period because the niiinon is outfitted exactly as it would have been at that time.

## 6. COMPARISON OF ARAPAHO TEXT DATABASE DATA VS. VR ELICITATION DATA

Speech elicited in the VR setting showed no evidence of distortion or speaker discomfort. On the contrary, the VR-elicited language is in some ways cognitively and structurally richer than everyday speech, to the point that it approaches the richness of traditional narrative forms. A key goal of this project has been to explore the efficacy of VR elicitation through establishing its

comparability to other methods of language documentation. To that end, both the VR recordings and a comparable set of non-VR recordings were interlinearized, annotated, and tokenized, and then sorted computationally and analyzed statistically. This was done in two ways. The first compared all the VR elicitations from Arapaho elders with an equal amount of video-recorded discourse from the Arapaho Text Database (Cowell 2014). This database contains the elicited ELAR material (text only) plus additional natural discourse, primarily in narrative format. Because this database is so extensive, we were able to choose comparison data that was similar to the VR data in terms of speech genre. Specifically, we selected narrative accounts which also contained associated cultural information and framing for the comparison. The aggregate non-VR data was drawn from six different speakers (three male, three female) who had been recorded in the 2000s. The data set consisted of audio- and/or video-recorded texts that were judged to be relatively equivalent to the long-answer format of the responses to the questions in the VR data. Eight texts from the Arapaho Text Database were used. Each text has a unique title code. The texts chosen are those with the labels JGSn, JGBear, Nfox, SBGH, Crazy, ECScalp, Bug, and BlClotH. This data contained roughly the same number of sentences (within 2%) as the VR data. The second way was by directly comparing the same speaker speaking about the same topic both in VR elicitation and in a traditional language documentation setting that had been fortuitously recorded at an earlier time.

In order to determine if the VR methodology was producing data comparable to that found in natural-discourse storytelling about key myths and landscape features, we tried taking a few different measures of the cognitive and grammatical complexity of the data produced. One measure of this type that has been used previously for Arapaho is the presence of subordinate clauses, which can be measured by counts of specific subordinating prefixes (Cowell & O'Gorman 2016, Cowell et al. 2017).

We focused on adverbial subordinate clauses because they are more common than complement clauses and relative clauses, and also because they are often grammatically and syntactically richer and more complex than the other clause types. In particular, they tend to express a richer set of aspectual and temporal relationships between the main clause and the subordinate clause than the other two types of clauses. They thus provide a heuristic of language richness and detail in narrative discourse. An invented example, showing a complex initial subordinate clause followed by a relatively simple main clause, is shown in Example 1 below:[3]

(1)   toh-uus-bii3woon-eit       ne-isonoo,   nih-'oxow-o'.
      when-PERF-cook.for-4/3s   1s-father      PST-feed-1S/3S
      'After she finished cooking [the food] for my father, I fed him.'

For this type of subordinate clause, the aggregated natural discourse data has 44 instances out of a total of 924 verbs; i.e., 4.76% of verbs occur in an adverbial subordinate clause while the VR comparison data has 55 instances out of a total of 821 verbs; i.e. 6.70%. So the VR data is producing comparable numbers of adverbial subordinate clauses compared to the non-VR data, and thus is syntactically rich in at least this respect.

Another measure that has been used to evaluate Arapaho syntactic complexity is the number of transitive verbs employed in discourse. In Arapaho, transitive verbs mark both subject and object on the verb; they are thus cognitively and grammatically more complex than intransitive verbs, which mark only the subject (Cowell et al. 2017). When we measured the number of tokens of transitive verbs with an animate object (TA verbs) and transitive verbs with an inanimate object (TI verbs) in the two sets of data, we found that there were some differences in terms of the overall number of transitive verbs being used. The VR-elicited speech has a lower percentage of TA verbs (55 vs. 201), but a higher percentage of TI verbs than the natural discourse data. These observations are summarized in Table 1.

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3    The following abbreviations are used in example 1: PERF – perfective aspect; 4 – obviative, i.e. "4th person"; 3s – third person singular; 1s – first person singular; PST – past tense.

| | TOTAL VERBS | TRANSITIVE VERBS WITH ANIMATE OBJECT (TA VERBS) | TRANSITIVE VERBS WITH INANIMATE OBJECT (TI VERBS) | TOTAL TRANSITIVE VERBS | TRANSITIVE VERBS AS PERCENTAGE OF TOTAL VERBS |
|---|---|---|---|---|---|
| Aggregated Natural Discourse Data | 924 | 201 | 64 | 265 | 28.7% |
| VR Discourse Data (For Comparison) | 821 | 55 | 110 | 165 | 20.1% |

Table 1 Comparison of use of transitive verbs in VR and natural discourse data.

Again, the proportions of total transitive verbs used are roughly comparable, though the proportion of types of transitive verbs used were not. For instance, there was a higher proportion of TA verbs in the non-VR data. We hypothesize that this is the result of the non-VR data being narrative in origin, in which two individuals are very often described by the storyteller interacting with each other, thus resulting in many instances of TA verbs. In contrast, the VR data asked the respondents about their relationships to the tipi and the landscape, i.e., inanimate objects. As a result, the VR data shows a much higher percentage of TI verbs compared to the narratives. This suggests that measures of syntactic richness in Arapaho can be quite sensitive to the speech genre in question, at least for some measures such as TI and TA verbs (a finding corresponding to the results reported in Cowell & O'Gorman 2016). It also shows that the speech of the consultants was sensitive to the specific nature of the VR topics (which in this case focused on inanimate objects) and the interview format, in which speakers were asked about their attitudes and relationships to those objects.

When Nii'eihii Neecee was previously recorded in a traditional language documentation context, he spontaneously decided to tell Cowell about the symbolic meanings of the Arapaho niiinon (ELAR 35c). In spontaneous description of the niiinon, he produced only 70 lines of utterances. When interviewed in a VR elicitation session for this project, he produced 310 lines on the same topic. So, the VR elicitation produced more than four times as much speech covering the same general content. This suggests the potential for the immersive visual aspect of VR to produce richer responses than simply talking in the abstract. Admittedly, the sheer volume of speech in the VR elicitation sessions cannot be attributed to VR alone, as it also reflects the fact that during the VR elicitation sessions multiple questions were posed, while in the traditional language documentation context Cowell simply listened to and recorded the account. These observations are summarized in Table 2.

| | TOTAL VERBS | TRANSITIVE VERBS WITH ANIMATE OBJECT | TRANSITIVE VERBS WITH INANIMATE OBJECT | TOTAL TRANSITIVE VERBS | TRANSITIVE VERBS AS PERCENTAGE OF TOTAL VERBS | ADVERBIAL SUBORDINATE CLAUSES |
|---|---|---|---|---|---|---|
| Aggregated Natural Discourse Data | 116 | 8 | 15 | 23 | 19.83% | 14 |
| VR Discourse Data (for comparison) | 394 | 17 | 51 | 68 | 17.24% | 14 |

Table 2 Comparison of consultant Nii'eihii Neecee's speech on the same topic in VR vs. natural discourse.

In this case, there is notably less use of adverbial subordination in the VR data relative to the total number of clauses. However, numbers of transitive verbs are similar in each case (17.24% for VR, 19.83% for non-VR). Once again, the VR data shows a high number of TI verbs relative to TA verbs even though in this case the topic is the same for both the VR and non-VR data.

We hypothesize that, since the speaker was asked about his and Arapahos' *relationship* to the inanimate object in the VR dataset, this produced many TI verbs of the form 'we used it', 'I see it', etc. Thus, the specific topic of the discourse would appear to be less important for demonstrating the linguistic structures used than it is for showing the way in which the speaker engages with,

or is asked to engage with, the topic. Put another way, the specific nature of the linguistic data produced is first a product of the mode of interaction between the speakers, and secondarily, of the mode of interaction between the speaker and the surrounding environment. The VR elicitation practice shapes the way they speak about the world around them, while on another level, the VR elicitation method creates new ways for the elders and their students to form relationships with traditional homelands from which they have been systematically and forcefully removed.

## 6. CONCLUSIONS

The VR elicitation method brings elder speakers of endangered Indigenous languages to places and times that would otherwise be impossible for them to access, producing results that are unique and valuable from both a cultural standpoint and language documentation standpoint. Analysis of the quantitative linguistic results obtained with VR are generally comparable, in terms of grammatical complexity, to the results obtained involving traditional narratives in the classic documentation context. The quantitative results also suggest that VR may produce specific linguistic patterns in the data that reflect both the highly interactive nature of the experience and the loose interview type of format used. The VR elicitations produced data comparable in richness to that found in traditional speech. This is distinctly different from the productions normally associated with interviews. This suggests that the interactional intensity of VR can compensate for the downside of interview-style elicitation, which tends to be more interviewer-controlled and discontinuous compared to a narrative. Thereby VR elicitation produces very rich linguistic results similar to a traditional narrative, which would not be expected in non-VR interview situations.

The harsh reality of Indigenous language and culture endangerment and loss demands new approaches to language documentation. In the words of Nookhoosei Niibei, a key Arapaho educator and language revitalization activist (personal communication, 2019-11-01):

> This project will reach the next generation by bringing our lands back to us and combining VR with our language; instead of competing with technology we are joining forces, so to speak! Let us continue to work hard together so that our sacred language will live and we can produce a whole new generation of fluent speakers!

VR elicitation is a new and promising tool in the tool kit for Indigenous language and culture preservation and revitalization.

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## COMPETING INTERESTS

The authors have no competing interests to declare.

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