Algorithm-based Troubleshooting for Improving Skill Acquisition in Toothbrushing Among Children with Autism Spectrum Disorder (ASD)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract
Intro: Autism spectrum disorder (ASD) is a developmental disability (DD) in which patients exhibit social and communication impairments, restricted interests, and repetitive behaviors (Christensen et al. 2016). Children with ASD and DD struggle with daily living skills such as toothbrushing. The STAR initiative at the University of Virginia has developed skillSTAR, an application that uses evidence-based behavioral practices to improve skill acquisition in daily living skills such as tooth brushing. Even with embedded support, the team anticipates that there will be users who require additional support to address common barriers to instruction (e.g., challenging behavior, lack of attending, sensory issues). The purpose of this capstone was to create an algorithm to guide users to additional online support.
Methods: With the guidance of Sartography, LLC, I have created an algorithm that will guide users (caretakers/educators) to troubleshooting resources based on identified barriers to instruction that they are experiencing while using the app. The algorithm was tested for validity manually and via an automated test function. I also have conducted a user experience survey, in which potential end-users were asked to reflect on the usefulness of the algorithm.
Results: Success rate was 100% for both the automated test function as well as manual testing. The inputted reasons have yielded the expected outputs, thereby proving that the tool can be used to successfully guide users to troubleshooting resources. According to the survey results, end users felt that troubleshooting resources would be useful (to varying degrees), and have suggested potential additional barriers to consider.
Conclusion: However, this algorithm can be improved through different ways such as adding more barriers to success skillSTAR trials. This algorithm can hopefully be used to improve user experience for skillSTAR, thereby improving toothbrushing and other daily living skills for children with ASD/DDs.

Keywords: Autism, Evidence-based practices (EBPs), troubleshooting, algorithm

Introduction

Autism Spectrum Disorder (ASD) is a complex developmental disability in which patients exhibit limitations in social interaction and communication along with the presence of restricted, repetitive patterns of behaviors, interests, or activities (Maenner et al. 2020; Smutkeeree, 2020). ASD can also be considered a group of neurodevelopmental disabilities (Smutkeeree, 2020).

ASD has become more commonly diagnosed among children throughout the past few decades (Johnson et al. 2007). Current data suggests that 1 in 54 children in the United States are diagnosed with ASD (Maenner et al. 2020). It is usually identified when a child is around 18 to 24 months old (Maenner et al. 2020).

ASD is screened through behavioral and developmental monitoring and developmental screening (Maenner et al. 2020; Christensen et al. 2016). According to the National Institute of Health (NIH, 2020), symptoms of ASD include (but are not limited to) the following: failing to respond to verbal attempts to gain their attention, difficulty identifying facial expressions, resistance to (even slight) change, being overly focused on certain interests, repetition of words or phrases, above or below average sensitivity to external stimuli, and performing everyday tasks (NIH,2020). Symptoms can also include challenges with communication, social interaction, repetitions of specific behaviors, and abnormal sensory sensitives and needs (Blomqvist et al. 2015). People with ASD also struggle with “building flexible predictions and expectations,” which is an impediment to thriving in the unpredictability of the social world and environment around them (Blomqvist et al. 2015).

While general symptoms are specified above, children with ASD display different characteristics depending on the severity of their symptoms and will experience dissimilar difficulties (Smutkeeree, 2020).For this reason, it is important to provide individualized treatment for each person diagnosed with Autism (Smutkeeree, 2020).

One common area that warrants intervention among individuals with autism is adaptive skills. Adaptive skills are those that are required for living independently, which includes social, communication, and daily living skills (Kenworthy et al., 2010). Particularly, children with ASD struggle with daily living skills more than their neurotypical peers and children with other developmental disabilities (Kenworthy et al., 2010). Daily living skills refer to skills that people need competence in to live independently (Hone et al. 2015). Examples include meal preparation, grooming oneself, and toothbrushing (Kenworthy et al. 2010).

One daily living skill that has major implications for health and wellbeing across the lifespan is toothbrushing. Tooth-brushing twice a day is extremely important to maintain oral health. However, due to the complex nature of the task (requiring many steps to perform), it is challenging for the child with autism spectrum disorder to perform this task, which results in the child displaying challenging behaviors or being resistant to performing the task (Smutkeeree et al. 2020). Not brushing teeth can result in poor oral health which usually affects people in the form of tooth decay, gingival disease, orthodontic issues, dental caries, and periodontal gum disease (Khatib et al. 2013; Campanaro et al. 2019). These conditions are detrimental to overall health because as it can lower a person’s quality of life including affecting their ability to eat certain foods and to sleep due to pain, suffering and weakness of gums (Campanaro et al. 2019). Another problem, specifically for children with ASD and other developmental disabilities is difficulty in verbally expressing that they are in pain, which results in said pain going unnoticed, which can then lead to more serious conditions such as diabetes (Campanaro et al. 2019).

In order to improve toothbrushing and other daily living skills, it’s important to design interventions that incorporate EBPs. EBPs are programs and/or practices that have been researched thoroughly and are empirically proved to provide impactful, highly-effective outcomes for children with ASD (Cook & Odom, 2013). According to Cook and Odom (2013), research for EBPs must meet these general standards: “research design, quality, and quantity”. EBPs are supported by high-quality, experimental research or single-case research (participants serve as their own control) (Cook and Odom, 2013). Some EBPs can also be defined by the way interventions are delivered (e.g. through a parent/caregiver, peer, technology, etc) (Wong et al. 2015). Currently there are 27 intervention strategies that are considered EBPs. EPBs to improve daily living skills include video modeling, prompting, and task analyzing skills, among others (Hong et al. 2015; Hume et al., 2021).

One of the ways that the UVA School of Education and Human Development is aiming to help children with Autism is through the STAR initiative. The purpose of this initiative is to promote transdisciplinary and interdisciplinary research that addresses socially significant issues facing people with autism, their families, and professionals who serve them.

For one of their projects, researchers working with the STAR initiative have developed skillSTAR, a tablet based application that uses evidence based behavioral strategies to address adaptive skills among children with ASD and developmental disabilities (DD). skillSTAR also incorporates graphing and progress monitoring. The goal is to put the EBPs in the hands of teachers and parents who are not formally trained in behavioral strategies, thus increasing access to EBPs (interventions to address adaptive behaviors).

Aims

1) **Develop an algorithm that will connect users to troubleshooting tools to address common barriers to success when using skillSTAR to improve toothbrushing skills for children with ASD**
2) **Evaluate the effectiveness of the algorithm based on automated and manual code validity tests**
3) **Solicit feedback from potential end-users related to the usability and helpfulness of the algorithm**

Rationale

Even with evidence-based practices and expert-driven strategies used for teaching toothbrushing, ASD is a complex disorder, and some children may need additional help to complete each step. In order to be able to provide the best experience for users and children, it is important to provide further guidance and more resources that can help the caregiver and/or educator work with the child to implement strategies to help them master a particular step of toothbrushing.

Therefore, to ensure the best experience for users, I worked with Sartography, LLC (a software company that develops bespoke apps) to create an algorithm (troubleshooting tool) using Python code that will point to troubleshooting tools based on the reason a child fails a trial. If a child fails a trial, it means that the child did not complete the step in the toothbrushing task at the prescribed prompt level. This component of the app represents an important step towards increasing the usability of the tool by caregivers and educators who do not have behavioral training.

Materials and Methods

Architecture of the Code

In order to write the python code for this troubleshooting tool, it is first important to construct the logic for the code (as displayed in Figures 1 & 2). The idea behind this algorithm was to direct users to the correct resource in order to ensure that they get the necessary information to help the child based on the reason the child failed the trial (i.e., did not complete the trial at the prescribed prompt level). As mentioned in the methods section, functions with if-statements were used to determine 1) the correct resource to direct a child to, and 2) if the reason wasn't sensory issues, challenging behavior, or lack of attending, the user can also be encouraged to have the child work with their service provider, and/or find a trained service provider for the child who can work with them one on one to really help them improve their toothbrushing.

For the final iteration of the code, there are four functions. Functions are code blocks that run and are "called" later in the code. In order to run a function, it usually needs parameters and inputs for said parameters. Some functions do not need inputs/parameters. The reason I have used a function as opposed to plain if-statements, is that the code can be called for future components for skillSTAR and future revisions of this troubleshooting algorithm. Each function is mainly designed to perform one type task (e.g. adding, returning a statement, returning a sum or difference between several numbers). The actual code is given in supplementary figure 1, and the conceptual logic is explained below.

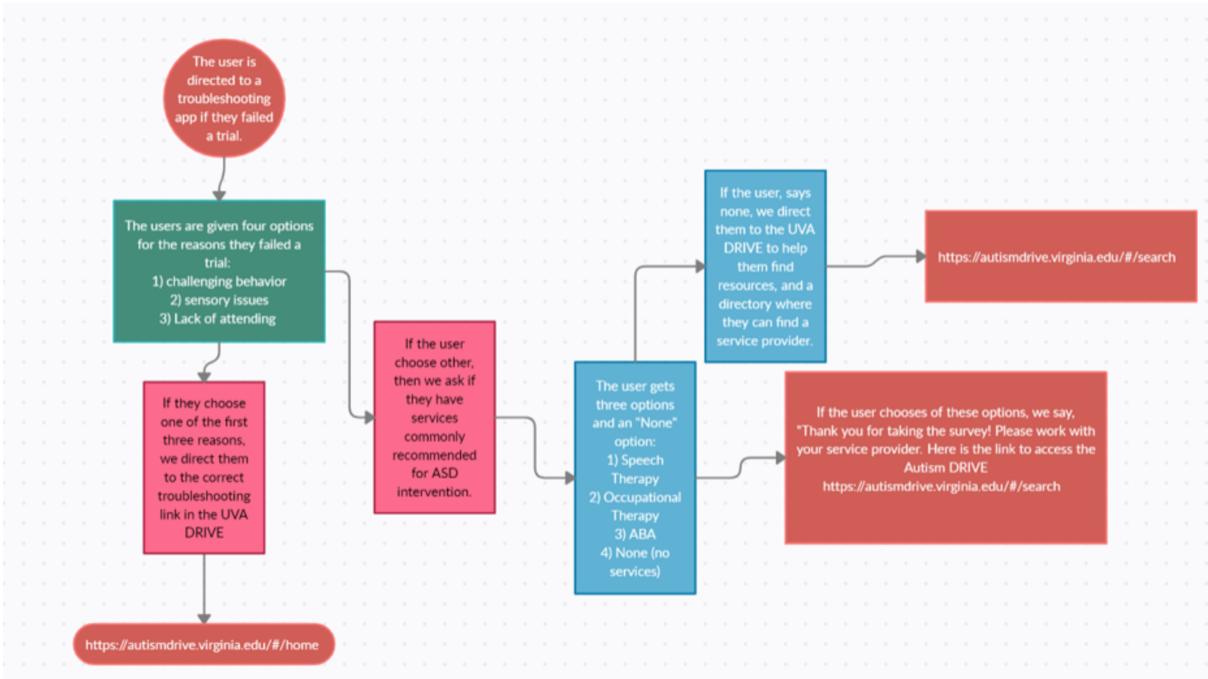
Conceptual Logic and Testing

If a child fails a trial, the user will be directed to the troubleshooting algorithm. The first question that the user will see is "What is the primary reason for failing to complete the trial at the current prompt level?", along with four options for the reasons: lack of attending, challenging behavior, sensory issues, and other. These options were included because they are common barriers to implementation of behavioral intervention according to the literature, and they lead to concrete and general recommended strategies for addressing the barriers. Then, other was added as an option because the researchers acknowledge that ASD is a complex disorder and that there may be a myriad of reasons for failing a child that are child, family, or context specific. If the user types of the first three reasons, they were directed to the respective troubleshooting resources. Current links are used as unique placeholders, and the pages will be added later.

If the user types other, then we ask them if they are currently receiving commonly recommended services for children with autism (namely speech therapy, occupational therapy , and applied behavioral analysis (ABA)), and we encourage the user to work with the service provider that they typed (e.g. speech therapist). We suggest these three options because we cannot ethically provide individualized treatment recommendations without observing a child. Troubleshooting resources are general and established recommendations that are basically suggestions on how to manipulate the environment to promote appropriate behavior.

If they typed None, then we direct them to the UVA Autism DRIVE. According to the Autism DRIVE website, "The Autism DRIVE enables secure storage and sharing of autism data, helping to monitor progress and outcomes.(AutismDRIVE, 2019)" "The system also provides access to resources for families and professionals -- infusing cutting-edge knowledge into community-based practices" (AutismDrive, 2019).

Figure 1 – This is the logic of the algorithm.



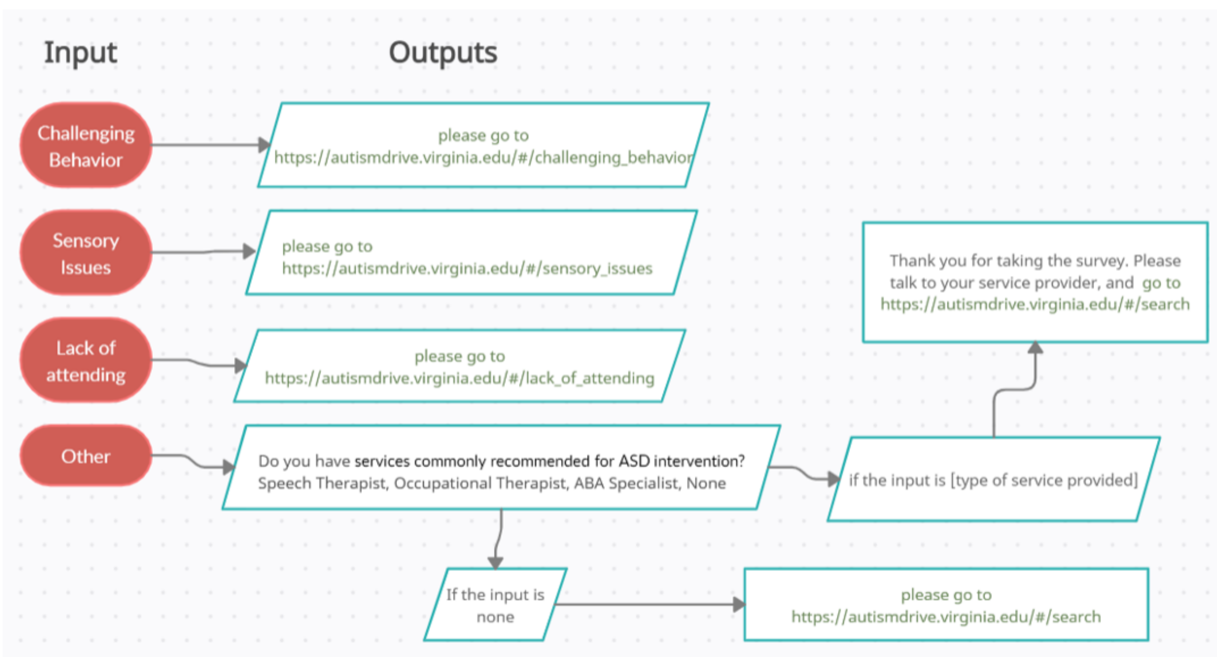


Figure 2 – This flowchart shows the algorithm's output.

It's important to ensure that this troubleshooting algorithm directs users to the right resource based on the reason they typed for failing a trial, and whether or not they have resources. My first method of testing was to try all input reasons, thereby conducting trials with 50 "participants" and iterating through the program to ensure that each respective input gives us the necessary result.

The other test I conducted was using an automated test function in a separate file where the tool would be called, and the test function would contain the three options, which would then be used to ensure that the actual output of each user input (e.g. lack of attending, etc. would be the same as the expected output (link)), and that the code wouldn’t throw out any errors.

The main difference between the two types of testing is that for manual testing, I iterated through the code 50 times in order to put in the different inputs, and when I conducted automated testing, I use a self.assertEqual function (referred in Supplemental Figure 2), to check the equality of my anticipated output to the actual output of the function.

Survey

Using Qualtrics, we surveyed potential users to gain more information about potential user experience for the trouble shooting algorithm. This survey included 12 questions, with the purpose of soliciting information about 1) whether having a troubleshooting algorithm and resources was useful, and 2) how the troubleshooting algorithm could be improved. We also wanted to take into consideration any barriers to success in trials that we hadn’t initially thought of when creating the questions and input options for our two questions.

This survey was sent out to 52 members of the STAR team consisting of professionals, family members, family support professionals. Of the 52 potential respondents, ten partially completed the survey and seven completed the survey in full. These seven responses were considered in our results.

In our first three questions, we gathered data on user demographics about their training in ASD, experience working with children with ASD, and the roles they serve in helping children with Autism and their families. The question about the users’ roles served in ASD along with their relationship are multiple-option questions as many people have more than one relationship to ASD (e.g. a parent, behavioral technician, specialist, etc), and can help people with ASD in more than one way. Training received is also a question that was asked to gather data on the level of expertise in the field. In order to gather user data about usefulness of troubleshooting resources, it's important to have a diverse population in a survey to avoid bias towards one particular type of people (e.g. “experts” in ASD, or only family members) (Starr, 2012). This would make it very difficult to generalize the results.

We asked likert-style questions, which are questions that require survey participants to rate something based on their “attitude (i.e. how strongly they agreed/disagreed)” towards the topic of the question (Joshi et al., 2015). Likert-scale questions were developed to provide options between yes/no extremes (e.g. Not Agree vs. strongly agree) (Joshi et al., 2015). For example, in our survey (Figure 6), our options for the likert-style questions ranged from Not helpful, somewhat helpful, helpful, and very helpful, and Not likely to Very likely. These options were important as they give users a range of options to choose from in terms of how useful they think an resource/intervention is (Croasmun & Ostrum, 2011) answers as opposed to yes/no questions. Plus, Likert-style questions measure customer/user/participants' feelings about a topic in a scientifically accepted and validated way (in the social sciences) (Joshi et al., 2015).

We also asked open-ended questions about factors we should consider when creating troubleshooting resources, and other reasons that children may not succeed in trials.   These open-ended questions gave users the full freedom to type in whatever factors they thought of that would make the troubleshooting resources more useful, thereby making the algorithm more useful since it can be used for directing users to more pointed, helpful resources.

Results

Algorithm

After using 50 test inputs and automated the test function (as shown in tables 1 and 2), we were able to conclude that the troubleshooting tool was indeed able to lead users to the correct link based on the input given in terms of the reason for failing a trial, and the need for a specialist. When conducting the test manually, I was able to iterate through the program to ensure that 1) each of the initial reasons can direct the user to the right resource. While the troubleshooting resources have not been added yet, I was able to manually test the effectiveness of the program by adding placeholder links where the ending of the link has been changed to match the reason for failing the trial. For example, as shown in table 1, if the user typed in challenging behavior as their input, they would get the following output: "Please go to https://autismdrive.virginia.edu/#/challenging_behavior."

As another example, after the user typed, "other" as one of their options, they are able to be directed to a directory of service providers so that they can find a service provider in their area who will be able to work with them 1:1 to better understand what exact issue the child has with mastering a particular skill in the trial.

As for the automated test (table 1), all the inputs and outputs were tested using a test function that contains an "expected output," and it runs the code to ensure that the expected output is equivalent to the actual output of the code. For example, if a user chose "speech therapy" as a service, the expected output was "Thank you for taking the survey. Please talk to your service provider, and go to https://autismdrive.virginia.edu/#/search." After running the automatic test function, it was shows that the actual output was "Thank you for taking the survey. Please talk to your service provider, and go to https://autismdrive.virginia.edu/#/search." Again, there was a 100% success rate with the program.

This was the same as the expected output, which again proves that the algorithm is able to direct users to the correct troubleshooting resource(s) based on the

Input	Output	Success Rate
challenging behavior	please go to https://autismdrive.virginia.edu/#/challenging_behavior	5/5--100%
lack of attending	please go to https://autismdrive.virginia.edu/#/lack_of_attending	5/5--100%
sensory issues	please go to https://autismdrive.virginia.edu/#/sensory_issues	5/5-100%
other - ABA	Thank you for taking the survey. Please talk to your ABA specialist, and go to https://autismdrive.virginia.edu/#/search	6/6--100%
other - speech therapy	Thank you for taking the survey. Please talk to your speech therapist, and go to https://autismdrive.virginia.edu/#/search	12/12--100%
other - occupational therapy	Thank you for taking the survey. Please talk to your occupational therapist, and go to https://autismdrive.virginia.edu/#/search	9/9--100%
other - None	please go to https://autismdrive.virginia.edu/#/challenging_behavior	9/9--100%

Table 1 – Outcomes for Manual Testing

Input	Output	Rate that Expected Output equals Actual Output
challenging behavior	please go to https://autismdrive.virginia.edu/#/challenging_behavior	100%
lack of attending	please go to https://autismdrive.virginia.edu/#/lack_of_attending	100%
sensory issues	please go to https://autismdrive.virginia.edu/#/sensory_issues	100%
other - ABA	Thank you for taking the survey. Please talk to your ABA specialist, and go to https://autismdrive.virginia.edu/#/search	100%
other - speech therapy	Thank you for taking the survey. Please talk to your speech therapist, and go to https://autismdrive.virginia.edu/#/search	100%
other - occupational therapy	Thank you for taking the survey. Please talk to your occupational therapist, and go to https://autismdrive.virginia.edu/#/search	100%
other - None	please go to https://autismdrive.virginia.edu/#/challenging_behavior	100%

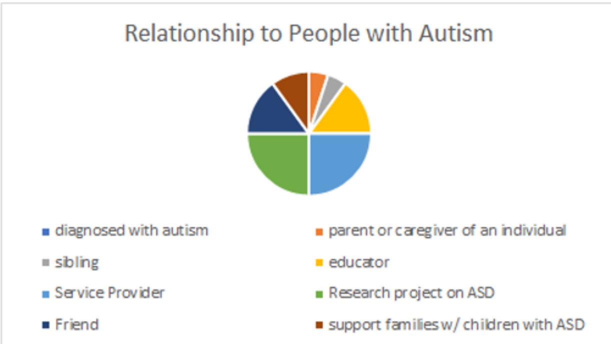
Table 2 – Outcomes for Automated Testing

reason they failed the trial and/or if they have a service provider.

Survey

Based on the demographic survey results (Figures 3-5), there are people from different backgrounds in terms of their role in helping people with ASD, level of training, and their relationship with Autism. One of the things I noted was that most of these participants had multiple answers (for the relationship to Autism question and the roles served in helping people with Autism). Even with seven participants, it is still helpful to get input from people from diverse backgrounds (in this area) along with diverse backgrounds in training, to really understand what features can be added to the application. Due to the fact that most participants had multiple roles and relationships with ASD, the percentages of answers (Figures 3 and 4) are based on the total number of roles played in helping people with ASD (ten roles for seven people), and the number of relationships with ASD (20).

Figure 3

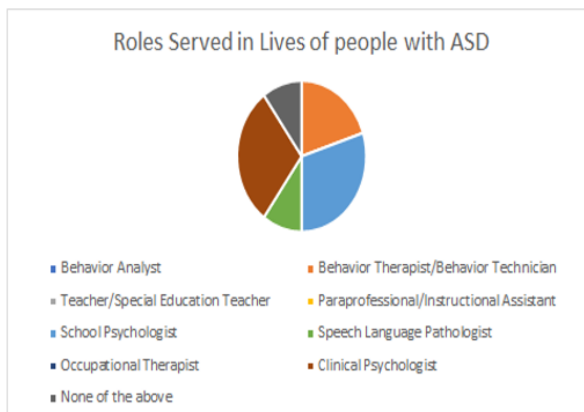


These roles and relationships have been played by seven people, which shows that each participant brought multiple perspectives. In terms of training in ASD, there was only one option that each participant could pick, so the total number of people the pie chart is measured out of is seven participants. According to figure 5 , there is one person who isn't trained in behavioral interventions, and that person is an educator, researcher in Autism, and a supporter for families who have children with ASD. There are two participants for each of the options about the level of training received (referenced in Figure 3. This again shows that there was a diverse pool of participants in terms of the training that was received.

Based on survey results of potential users (shown in figure 6), troubleshooting resources (videos and PDFs) are helpful to varying degrees. According to Figure 6, PDF resources have received more ratings in terms of likeliness of use (i.e. two users are somewhat likely to use PDF resources, one user is very likely to use PDF resources, and four users are likely to use them). This shows a slightly greater likeliness of use as compared to video-based resources (where three users will somewhat likely use video-based resources and four users will likely use them). These questions affirm the usefulness of troubleshooting resources (both video and PDF), which also shows that it is helpful to create the algorithm that directs users to said resources.

Figure 4

Figure 5



The survey results also revealed that five out of seven people would use the resources and connect to the Autism DRIVE to get in contact with a service provider if connected. Plus, all seven users felt that directing users to service providers would be helpful (in varying degrees). This finding suggests that it would be helpful to connect users to a directory of service providers who would be able to work with the child to provide one-on-one support for the child.

According to the testing results for both the algorithm as well as the survey, I was able to establish that the troubleshooting algorithm is able to direct users to the correct resource based on their input for the reason the trial was failed, and it's able to direct users to the correct resource based on the input they put in for the type of services that the child has.

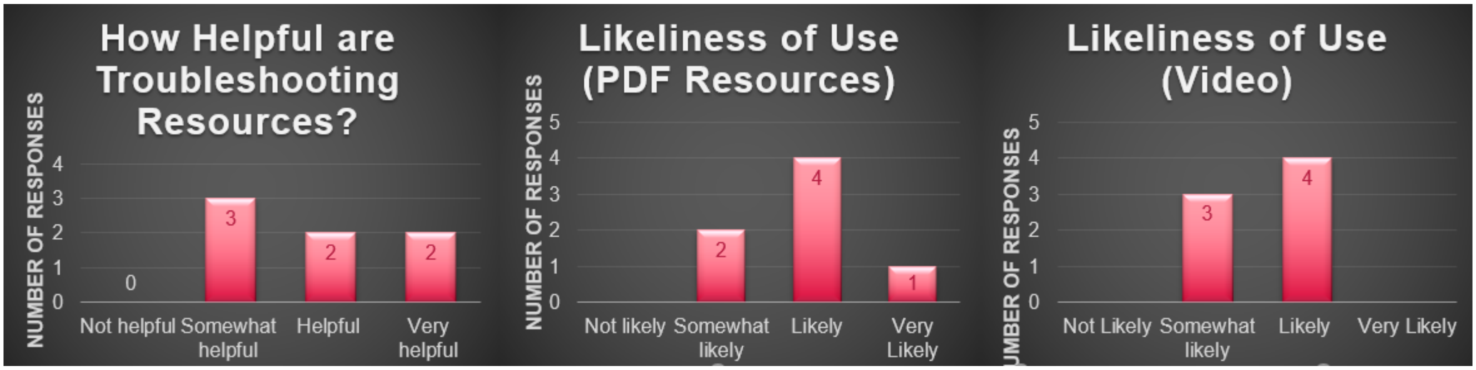
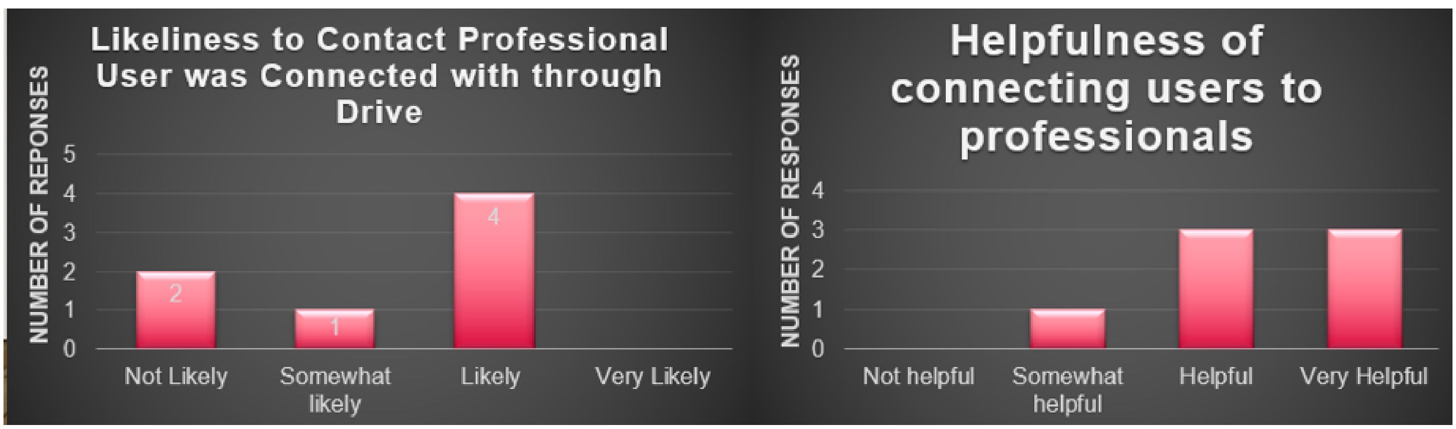


Figure 6 - Troubleshooting Resource Questions

Figure 7 - Troubleshooting Resource Questions



Summary and Conclusions

The purpose of this capstone was to create an algorithm that would direct users to troubleshooting resources, and to ensure that troubleshooting resources are useful and helpful for users. In the scope of this capstone, I developed a functioning algorithm (Aim 1), tested the algorithm (Aim 2), and used a survey to get data on user experience (Aim 3).

Troubleshooting algorithms could be used to help users find resources (in the from of PDFs would be especially helpful to users because they will be able to better address the problem in the trial, which will then personalize the experience of the skillSTAR application, thereby improving skill acquisition in toothbrushing for as many participants as possible (in a personalized way).

Soliciting feedback via surveys was helpful for several reasons: 1) affirming the usefulness of the algorithm, 2) affirming the usefulness of troubleshooting resources (Videos/PDFs) - i.e. people are likely to use them for additional support, and 3) the current skillSTAR application along with this algorithm can be improved, and we got some insights on how to improve the application. These are important reasons, as we want to ensure that we are able to provide as much support as possible for the children in the skillSTAR trials, and are able to accomplish the specific task in the toothbrushing process.

Overall, I was able to accomplish my three aims by creating a algorithm that directed users to troubleshooting resources based on the reason for failing a trial, and I was able to affirm the usefulness of the tool as well as getting input on how to improve the questions and input options such as adding more options to "reasons the user failed a trial," and even breaking down the three initial reasons (challenging behavior, lack of attending, and sensory issues) into even more specific reasons.

The success of this tool and the skillSTAR application would greatly benefit the field of Autism research, as the skillSTAR app in particular uses expert-driven EBPs that aim to help children with daily living skills. For this capstone project, the skill is toothbrushing, but skillSTAR is hoping to implement this measure for other daily-living/self-care skills.

Limitations and Future Work

While I was able to create this application and accomplish aims, there are several ways I can improve upon the application, and/or assumptions I can re-evaluate. One of the first things the team for STAR will be doing is adding the aforementioned troubleshooting resources in the respective folders in the Autism DRIVE. These resources contain evidence-based strategies to help users.

The algorithm was created with the assumption that commonly experienced barriers to intervention include challenging behavior, sensory issues, and lack of attending). These three options were identified because they are common barriers experienced by practitioners and caregivers that we can provide actionable resources for. By "actionable resources" I meant evidence-based, preventative strategies. We could possibly add other barriers under the "reasons" question (like the ones I mentioned earlier).

However, if we try to get too specific on the reason failed, there's the ethical dilemma of "Will the skillSTAR team enter an informal therapeutic relationship with this user and their child/student (when they aren't supposed to)? This dilemma is somewhat similar to the ones that medical professionals w/ active social media accounts face---they can't give "patient-specific advice to followers."

We also assumed that all users could afford local service providers such as BCBAs, occupational therapists, etc., even though they may not be able to do so. The skillSTAR team is also considering connecting people to case management providers for this (as suggested by the feedback in the survey). A possible future direction that the skillSTAR team is considering is to connect users to local family navigators or social workers who can help them navigate the assessment and intervention process.

When designing this troubleshooting tool, I had given three types of services as options (i.e. speech therapy, occupational therapy, and ABA). There are more than three types of service providers, but these were selected because they commonly work on the intervention side of ASD. In future iterations, we can add more types of services providers as options for the question about service providers.

Also, another limitation in this algorithm is that we are assuming that there is only one reason that a child failed a trial, and it could be more than one of the initial reasons. However, the reason for this is that we want the user to address the primary reason that the child failed the trial. Having one reason can help the user implement targeted EBPs for one specific problem instead of overwhelming the users with multiple intervention recommendations all at once.

Another assumption that was made was that the user knows why the child had failed the trial, when in reality the child may (or may not) be able to communicate the reason they failed the trial, and the user may always be able to detect the particular reason that the child wasn't able to complete the trial.

The skillSTAR app and the algorithm will continually be improved upon to ensure the best user experience, which will hopefully enable all users to increase their skill acquisition in daily living skills (toothbrushing for this project). If the app is successful, it can be used to teach other important life skills as well.

End Matter

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