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Repeat Recall Test Literature Review

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The Repeat Recall Test (RRT): A Review of the Literature

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Communication is complex, requiring two or more individuals to both share and receive information. There are many factors that determine an individual's potential to be successful in a communicative setting. For speech understanding, success comes not only from being able to hear the communicative partner, but also a strong lexical repertoire and cognitive ability (Slugocki et al., 2018). Listening and remembering in communication requires cognitive energy. Moreover, environmental factors, primarily noise, can cause an individual to feel they are putting forth too much effort and begin to lose tolerance to stay in the environment. This causes the listener to lose their cognitive energy. It is important for audiologists to be able to assess a listener's speech understanding in noise along with their cognitive ability and the way it interacts with their perceived effort and motivation to communicate. (Slugocki et al., 2018) To that end, Francis Kuk and other researchers in the Office of Research in Clinical Amplification (ORCA) developed the Repeat Recall Test (RRT) to serve to efficiently assess speech-in-noise performance and verbal working memory by testing repeat ability, recall ability, effortfulness, and tolerance (Office of Research in Clinical Amplification-USA WS Audiology, n.d.). The RRT is a sentence test that can be conducted using a computer with Windows 7 or higher, the necessary RRT program, and two loudspeakers or headphones (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 4:00, Operations). The results of the RRT might be useful to audiologists as they plan and execute treatment.

Methods

A search of literature was conducted during the fall of 2022. The primary databases utilized were PubMed, Academic Search Complete, Web of Science, and Google Scholar. The literature discussing the RRT is at its infancy. Consequently, many of the references in this

review were largely based on the resources listed on the ORCA webpage ORCA-USA is a hearing research facility of WS Audiology, a hearing aid company (Office of Research in Clinical Amplification-USA WS Audiology, n.d.).

Repeat Recall Test (RRT) – Construction

The Repeat-Recall Test (RRT) is a sentence test that contains five different themes/ topics. Those themes are food and cooking, movies and books, shopping, sports, and music. Each theme contains seven lists, each of which contains two sets of six sentences. One set of six sentences is high context, while the other is low context. An example of a high context sentence would be "Keep the ice cream in the freezer." A low context sentence would look like "Keep the ice foods in the lemon." (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 32:32, Rationale and Development). Both sentences in the high/low context groups have the same sentence structure, as well as the same location for target words, the only difference is the change in meaningfulness (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 33:30, Rationale and Development). Table 1 displays the topics, topic word count, and reading levels found in the RRT.

Table 1

The RRT – Speech Materials

	Target Words			Flesch Reading Levels	
Topic	***Nouns***	***Adjectives***	***Verbs***	***Reading Ease***	***Grade Level***
Sports	91	30	19	76.6	4.2
Shopping	95	35	10	69.5	5.2
Music	92	28	20	78.1	4.0
Books&movies	87	26	27	76.4	4.2
Food	92	29	19	81.8	3.4
Practice	13	5	2	94.3	1.7

From *RRT - Repeat and Recall Test* (*Rationale and Development* video, 35:32), by Office of Research in Clinical Amplification–USA, n.d. (https://www.orca-us.info/en/research/rrt).

For the presentation of the RRT, speech is presented in the front at 75dB SPL, which is a high and audible input level. The RRT was created to be a sound field test. This allows the test to be conducted with or without the patient using their hearing aid for most patients. The noise options for the RRT include a 2-talker babble and speech shaped noise. Either of these noise options can be presented at zero or one hundred eighty degrees azimuth. Kuk does not list a specific scenario where one option is superior, so the azimuth appears to be determined by the clinician's discretion. During the test, the noise is presented at five different signal-to-noise ratios (SNRs), zero, five, ten, fifteen, and quiet.

RRT – Protocol

To start the RRT, it is necessary to provide training, so the patient understands the instructions. For training, the patient is presented with at least one to two low context lists from the practice theme at a 10dB SNR. Once the patient is comfortable with the procedure, the

clinician may move on to the actual assessment. The methodology will be explained below as it is the same as the testing phase.

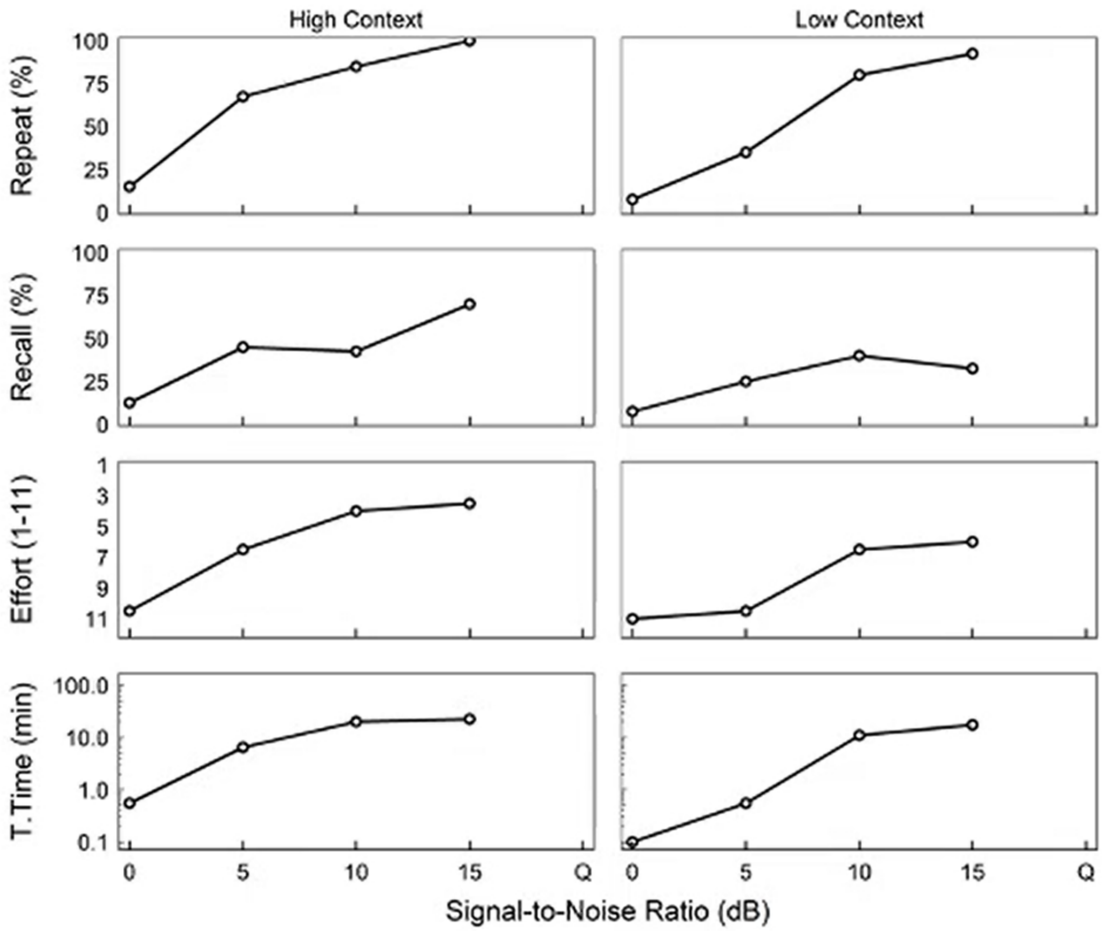
Beginning the testing phase of the RRT, the clinician selects a theme and a random signal-to-noise ratio (SNR) that is not zero. Once the SNR is selected, the program generates a new list of six low context sentences. The sentences are then presented to the patient. Following each sentence, the patient repeats, and the clinician scores every target word repeated. After the six sentences have been presented, the clinician asks the patient to remain quiet for a fifteen second rehearsal period. This period is intended for the patient to take time to reflect on what they have heard before they are asked to recall. Following the fifteen second rehearsal period, the recall portion of the test begins. The patient attempts to recall the six sentences. The clinician scores only the target words for the sentences. Immediately after the recall portion, the test moves to subjective ratings. The clinician asks the patient how effortful it was to listen in the presented SNR on a scale of 1 to 11. 1 would be considered not effortful, 10 would be considered very effortful, and 11 means the patient gave up. The clinician then asks the patient how long between 0 to 120 minutes could the patient tolerate that environment. Following the subjective ratings, the clinician saves the results. After saving the results, the process is repeated at the same SNR, but with high context sentences. Once the test has been completed with the high context sentences, the clinician chooses a random, different SNR. The computer then generates a different six low context sentences and the test is repeated until the patient has been assessed at all five SNRs. When the patient has completed all testing, the total time taken should be around 20-25 minutes (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 44:50, Rationale and Development).

RRT Results

Upon completion of the RRT, the program generates performance intensity (P-I) functions. Examples are shown in Figure 1. Displayed are eight different functions. They are broken into two columns, one for high context, the other for low context. Within each column are four functions. On each function, the x-axis corresponds to SNR, while the y-axis changes for each function. In the top row, the repeat score is interpreted as a percentage. In the second row, the recall score is interpreted as a percentage. In the third row, the effort rating is displayed. Finally, in the fourth row, the tolerable time is recorded in minutes.

Figure 1

The P-I Function Allows Estimation SRT at Different Criteria (75% & 85%)



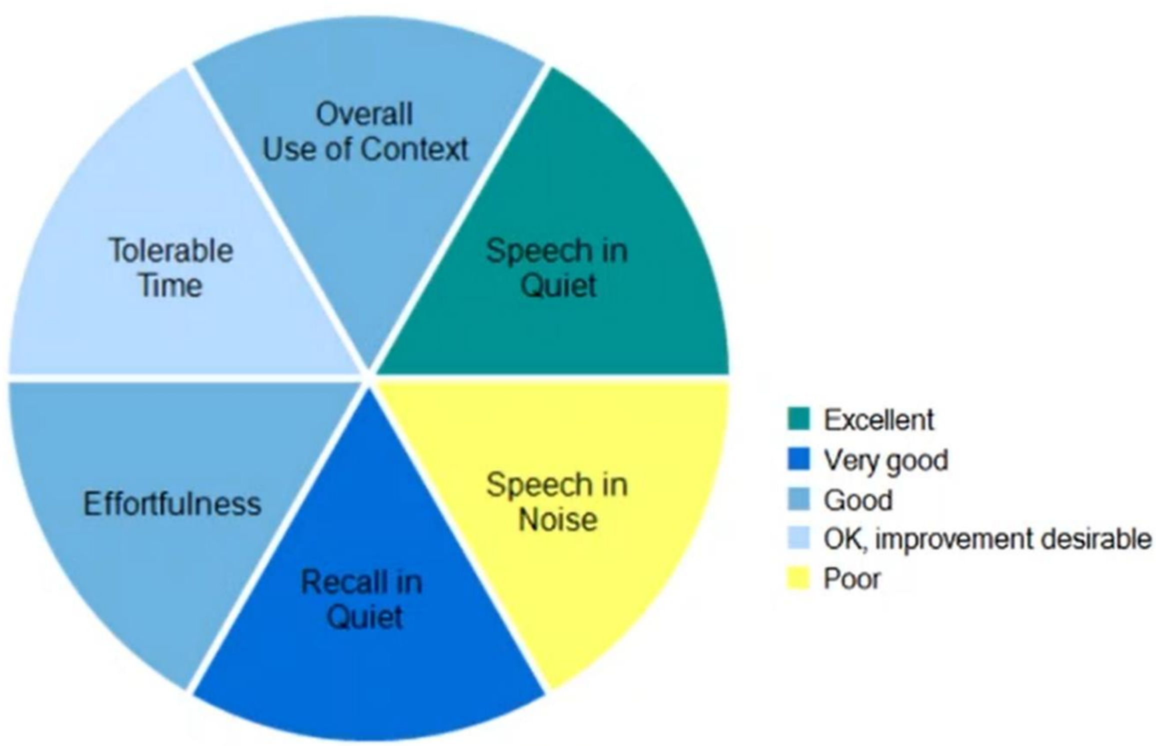
Note. The results are reported as P-I functions. SRT = Signal to Noise Ratio. From *RRT - Repeat and Recall Test* (*Rationale and Development* video, 49:44), by Office of Research in Clinical Amplification–USA, n.d. (https://www.orca-us.info/en/research/rrt). Copyright by Office of Research in Clinical Amplification–USA WS Audiology. Reprinted with permission.

In addition to the P-I functions, the RRT program generates a profile plot. The profile plot provides no new clinical information, rather it summarizes the information gathered by the

RRT in a way that is easy for the clinician to communicate with the patient. There are six sections to the plot, overall use of context, speech in quiet, speech in noise, recall in quiet, effortfulness, and tolerable time. Each section is given a summary interpretation which could be excellent (greater than or equal to the 95 percentile), very good (75 through less than 95 percentile), good (25 through less than 75 percentile), ok (5 through less than 25 percentile), or poor (less than 5 percentile). Figure 2 shows an example of the profile plot.

Figure 2

A Profile Plot to Simplify Patient Explanation



From *RRT - Repeat and Recall Test* (*Rationale and Development* video, 1:16:37), by Office of Research in Clinical Amplification–USA, n.d. (https://www.orca-us.info/en/research/rrt).

What Does the RRT Test?

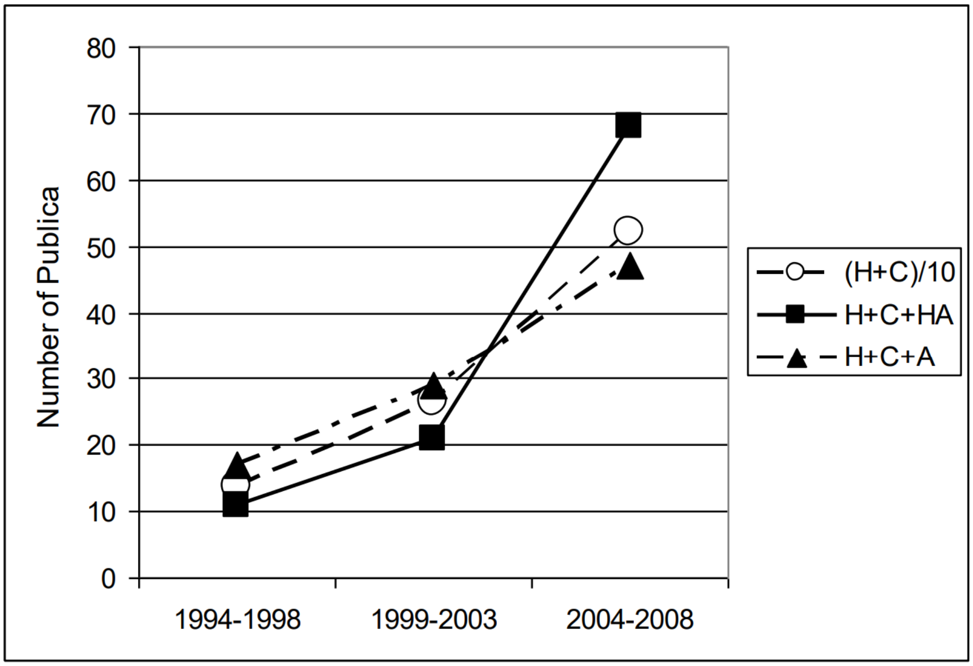
As mentioned in the opening paragraph, the RRT is used to test several subskills important to communication. Those subskills are discussed below.

A Need to Test Cognition

To be successful in communication, a listener needs more than just being able to hear stimuli. Another contributing factor to communicative success is a listener's cognitive abilities. In recent years, there has been an increasing number of studies on the relationship between cognition and hearing. Figure 3 shows the number of publications in three five-year periods from 1994 through 2008.

Figure 3

A graph of the number of publications of research on hearing and cognition



Note. "The number of publications in each of three five-year periods, based on bibliographic search in PubMed. Open circles represent the number of articles on hearing and cognition divided by 10. Triangles represent the subset of the articles on hearing, cognition and aging. Squares represent the subset of the articles on hearing, cognition and hearing aids." From "The Emergence of Cognitive Hearing Science," by S. Arlinger, T. Lunner, B. Lyxell, and M. K. Pichora-Fuller, 2009, *Scandinavian Journal of Psychology*, *50*(5), p. 372 (https://doi.org/10.1111/j.1467-9450.2009.00753.x). Copyright 2009 by the authors. Reprinted with permission.

Towards the end of the 20th century, there were multiple factors that led to the increase in the need for auditory and cognitive research, which include the need to understand how listeners perform in more ecologically realistic situations (Bregman, 1990; Handel, 1989; McAdams & Bigand, 1993; Neuhoff, 2004), how lifespan changes and impairments affect performance

(Schneider & Pichora-Fuller, 2000; Wahlin et al., 2006), how to design new communication technologies using advanced signal-processing and more customized ergonomics (Edwards, 2007), and how to implement educational and rehabilitation programs to enhance performance based on evidence of brain plasticity (Arlinger et al., 2009; Kraus et al., 1995; Tremblay, 2007).

Two of those factors can be seen prominently in the RRT. First, the RRT seeks to assess performance in ecologically realistic situations. That can be seen in the testing of different SNRs. Second, the RRT functions to give clinicians an outline of the intervention strategies necessary to enhance the patient's performance.

Working Memory

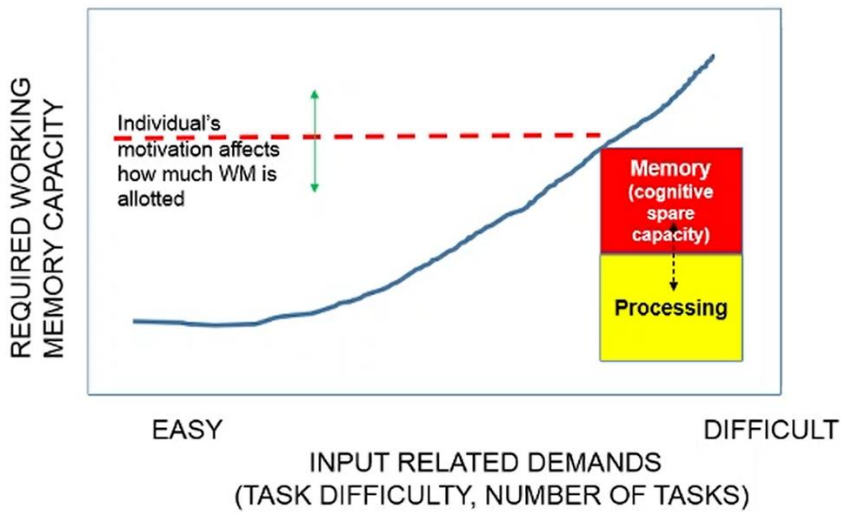
Cognition has many subcategories, but the one Kuk finds the most important for communication success is working memory (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 1:50, Rationale and Development). Lotfi et al. (2016) defined working memory as the ability to retain and manipulate information. An example of working memory in use is giving someone instructions on how to get to a location. The speaker must form a visuospatial representation of the area, determine the best route, then turn it into a verbal instruction that the listener is able to understand (Baddeley, 2007). During that process, once a visuospatial representation of the area is formed, it is retained in memory. While it is being retained, the information is being manipulated to find the optimal route, then being turned into spoken directions.

Working memory is not unlimited; when someone engages in a cognitive task, they inevitably must use working memory. Depending on the difficulty or number of tasks an individual is engaged in, their required working memory changes. Figure 4 demonstrates a direct

correlation between input related demands from easy to difficult and required working memory. Additionally, the red dotted line shows that an individual's motivation can shift their allocation of working memory capacity.

Figure 4

A Simplified Explanation of Working Memory



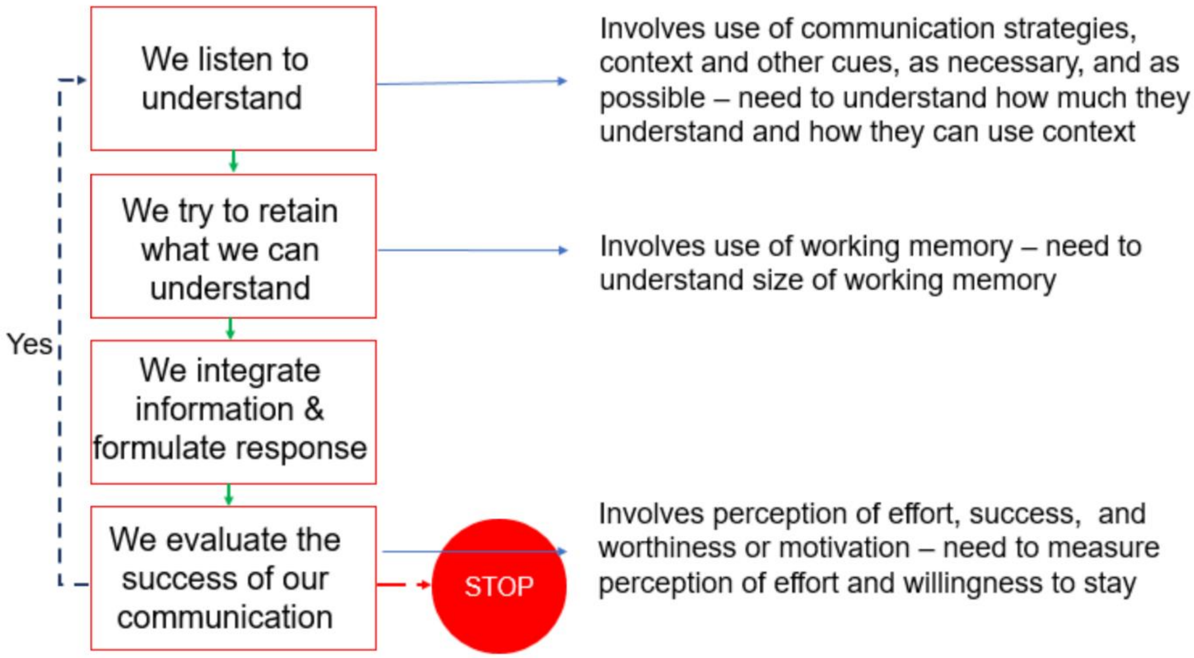
From *RRT - Repeat and Recall Test* (*Rationale and Development* video, 5:19), by Office of Research in Clinical Amplification–USA, n.d. (https://www.orca-us.info/en/research/rrt). Copyright by Office of Research in Clinical Amplification–USA WS Audiology. Reprinted with permission.

To illustrate how working memory is used in a communication setting, Kuk provides a flowchart shown in Figure 5. The flowchart demonstrates how in a communication setting, we listen to understand, then we try to retain what we can understand. This retention is where working memory comes into play. If an individual has a strong working memory, they will successfully retain what they heard in conversation, but if someone has a poor working memory,

they may not retain what their communication partner has said, resulting in a poor evaluation of their own communication success, causing them to lose interest in the conversation.

Figure 5

Flowchart of Realistic Communication



From *RRT - Repeat and Recall Test* (*Rationale and Development* video, 25:02), by Office of Research in Clinical Amplification–USA, n.d. (https://www.orca-us.info/en/research/rrt). Copyright by Office of Research in Clinical Amplification–USA WS Audiology. Reprinted with permission.

Working memory is an essential skill for communication that deserves to be assessed by audiologists due to the essential role it plays in the retention and manipulation of information during conversation.

Intelligibility of Speech in Background Noise

Working memory is exercised in the presence of background noise. While in a noisy environment, a decline in memory occurs because an individual focuses their attention on picking out speech from the noise rather than remembering the words they have just heard (Heinrich et al., 2008). When an individual has a good working memory, the competing auditory streams are found to be less distracting, leading to those listeners being more capable of separating speech from background noise (Lotfi et al., 2016).

Recall

The measurement of working memory is not commonly tested by audiologists. Nonetheless, working memory can be tested, and two such tests are discussed below. The first test is the Reading Span Test. The Reading Span Test has patients read sets of sentences, ranging from 2 to 5 sentences, and then attempt to recall the final word of each sentence after reading the set (Friedman & Miyake, 2004). The Reading Span Test is a commonly used test for assessing working memory, but in an audiologic setting, where hearing is most relevant, a test where the patient only has to read may not be practical. Another common working memory test is the Word Auditory Recognition and Recall Measure (WARRM). The WARRM test, in many ways, serves as an auditory counterpart to the Reading Span Test, making it more relevant for audiologists (Daneman & Carpenter, 1980). The WARRM contains 100 monosyllabic words organized in set sizes of 2, 3, 4, 5, and 6 words with 5 trials in each set size. The WARRM stimuli, which are presented in quiet, consist of a carrier phrase followed by a target word (Smith et al., 2016). After the last target word in each trail, there is a 3000 msec silent interval and then a 500 msec, 500-Hz tone that serves as a recall prompt (Smith et al., 2016). To summarize the WARRM, it has the patient repeat single words in a quiet environment.

For testing working memory, the RRT has its own recall portion. After being presented with six sentences, the patient is given a fifteen second period to think through the sentences, then they are asked to recall them. Each sentence contains 3-4 target words. Six sentences are typically the max that someone can recall. Additionally, the RRT tests recall at different SNRs, by doing this, the clinician can get an idea of how the presence of background noise stresses the patients' working memory. By testing recall in background noise, the RRT provides more measurements than the Reading Span Test and the WARRM.

Speech-in-Noise Performance

In addition to assessing verbal working memory, the RRT tests a patient's speech-in-noise performance. The focus of audiology is auditory impairment and how it relates to disordered communication (Stach & Ramachandran, 2021), including understanding speech in noise. Many audiologic tests assess subskills of communication by having the listener complete actions such as detecting the presence of a pure tone (i.e., pure-tone audiogram; Musiek et al., 2017); repeating monosyllabic words (i.e., word recognition score; Shi & Zaki, 2014)); or repeating spondees (i.e., speech recognition threshold; Ramkissoon et al., 2002). However, these tests might not give a good estimate into how successful a patient will be in a real-life communication setting. To get an estimate of a patient's speech-in-noise performance, the RRT tests the patient's ability to repeat presented sentences at various signal-to-noise ratios that are like those found in realistic communication settings. The following sections will break down the elements of the RRT that test speech-in-noise performance and how it is reflective of real-world communication scenarios.

RRT SNRs

When developing the RRT, it was important to Kuk that the test simulated realistic conditions (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 31:11, Rationale and Development). To simulate realistic listening environments, the RRT tests patients at zero, five, ten, and fifteen SNR. These SNRs are consistent with a study by Wu et al. (2018) conducted to determine the distribution of SNR in realistic communication environments. (Wu et al., 2018) Their findings showed that the median SNRs of situations such as “outdoors,” “traffic”, and “indoors crowd” were 9.7, 5.6, and 5.3 dB, respectively. Similarly, Smeds and others (2015) found the median SNRs of “outdoors,” “car,” and “department store” are 10.9, 3.6, and 2.3 dB, respectively. Finally, Smeds et al. (2015) also reported that for speech-in-babble noise, the average SNR was 5 dB.

RRT Testing Quiet

In addition to testing at various SNRs that replicate realistic communication environments, the RRT tests in quiet. Kuk explains that when testing in quiet an accurate representation of how a patient communicates in a noisy situation is not provided, but by recognizing words in quiet, the clinician is given a look into the patient's potential despite their hearing loss (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 27:45, Rationale and Development).

In addition to giving an insight to a patient’s potential, testing in quiet has use when testing patients with severe hearing impairment, specific language impairment, and for multicultural patients (Neumann et al., 2012). In a study by Nabelek (1988), 40 subjects of differing age and hearing level were tested on vowel identification in quiet, noise, and reverberation. Subjects were split into four groups based on their level of hearing loss. Upon completion, in noise, all four groups performed differently, but when tested in quiet, the groups

performed the same except for the group with greatest hearing loss (Nabelek, 1988). Given that testing in noise gave different results for all groups, testing in quiet stands as the best option for assessing a patient's potential to succeed in a communication environment.

RRT Context

An important aspect of the RRT is that it tests at high and low context. Context includes knowledge of what constitutes a well-formed sentence within the language, considering knowledge of word frequency, word familiarity, and the use of morphosyntactic, semantic, and situational cues (Grant & Seitz, 2000). Testing context gives a look into the cognitive capacity a patient uses for context in a communication setting, and how much listeners use context effectively during the test reflects their cognitive capacity. Research has suggested that by using context cues, a listener employ cognitively driven mechanisms over perceptually driven mechanisms in order to process information (Pichora-Fullet et al., 2016). It was found that in the high context sentences at highly positive SNRs, hearing impaired listeners outperformed listeners labeled with normal hearing. Both groups had similar scores on tests of cognition, so the hearing-impaired group did not score higher due to a superior cognitive ability, but it is likely that they were able to find success due to employing the efficient rehearsal strategies they have acquired from their communication experiences with a hearing impairment (Slugocki et al., 2018). This shows that testing context can also give insight into a patient's ability to use their listening strategies.

Repeat

The testing at different SNRs and contexts leads to the repeat portion of the RRT. Patients are presented with six different sentences at each SNR and asked to repeat each one immediately

following the presentation. Kuk describes two different pieces of information that can be gathered by this testing. First, testing repeat in quiet gives insight on the potential for a patient to understand speech despite their sensory loss. Second, by testing repeat in noise, the clinician can get a measurement for the effectiveness of the patient's peripheral and cognitive processing. (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 28:20, Rationale and Development). The repeat score is also used in estimating the patient's working memory. Upon completing the RRT, when the program generates the P-I functions, if there is a point on the repeat curve where the patient scores 95% or higher, the place on the recall plot with the same SNR is likely to be an accurate estimate for the working memory of the patient (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 52:53, Rationale and Development).

Subjective Qualities

When a listener is engaged in conversation, they will reach a point where the fatigue from listening in a noisy environment causes their willingness to partake to degrade. This amount of time will vary from listener to listener. Kuk lists that willingness to remain in conversation becomes degraded due to the listener's perceived understanding of the message weakening, an increased effort required to hear the message, and the listener losing internal motivation to engage with the messenger (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 29:37, Rationale and Development). By getting a measure of a listener's subjective qualities of communication, the clinician will be able to examine how the listener copes with a given listening condition and how that may alter their communication performance, even if they are capable of understanding speech in the given environment (Slugocki et al., 2018).

Listening Effort

To get a measure of a listener's subjective qualities of communication, the RRT tests two areas, the first of which being listening effort. Listening effort covers many concepts, such as the engagement and control of multiple possibly distinct neural systems for information processing, and the affective response to the expenditure of those resources in a given context (Francis & Love, 2020). When a person is engaged in conversation, there is more involvement cognitively than the auditory functions of the periphery, including selectively attending to sound sources, storing information in memory, using context information to improve understanding, resolving ambiguities, and generating appropriate responses quickly (Sarampalis et al., 2009). In different environments, the listener will need to rely on different quantities of cognitive resources. The reliance on cognitive resources is reflected in the listener's perception of the effort they put forth to stay engaged with the conversation. If the listener feels that a conversation is too effortful, they may disengage and in certain cases feel exhausted. For example, Hetu et al. (1988) conducted interviews on individuals diagnosed with a hearing loss who said that the fatigue from their hearing difficulties and coping mechanisms was so severe that they would be "… too tired for normal activities" after finishing their work. Said differently, two listeners might score the same on intelligibility, but exert different amounts of effort in the process (Winn et al., 2018, p. 2). By adding listening effort to the test, it could be found that one listener is using considerably more effort to achieve the same score, causing them to feel less successful in communication.

Tolerable Time

The other subjective quality of communication tested by the RRT is tolerable time. After completing the repeat and recall assessment at each SNR, the patient is asked how long they could tolerate the noise of the current environment. Kuk explains that noise can be viewed as a disruption (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 29:18,

Rationale and Development). The length that this disruption can be resisted such that it does not affect the listener's willingness to stay in a communication environment is measured in tolerable time. By measuring tolerable time, the clinician can get an estimate of the willingness of the listener to remain engaged in noise or their potential success in daily noisy situations.

Intervention

Upon the completion of the RRT the clinician can develop a management plan for the patient. If the patient has scores equal to or better than normal (50% when compared to the age-normed criteria), their current amplification is adequate, and they are most likely satisfied with their communication performance. In situations where the patient scores equal to or better than normal on recall, but poorer than normal on repeat, it is a sign that their current amplification is insufficient and there needs to be an improvement in SNR for effective communication in noise. Kuk offers treatment examples. To improve performance in situations with a low SNR, Kuk suggests the implementation of a noise reduction algorithm that activates at poor SNR, the use of directional microphones, or teaching the patient to improve context use by asking questions. When a patient receives normal repeat score, but insufficient recall scores, their amplification does not need to be adjusted, but they may benefit from training to improve their working memory. This scenario is very unlikely. In instances where the patient scores poorer than normal on both their repeat and recall scores, the intervention will be the same as for normal recall, but poor repeat, with the addition of rehabilitative training for their working memory (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 30:00, Clinical Applications).

Aside from the repeat and recall scores, other results of the RRT are able to suggest different intervention strategies. For example, in situations where a patient shows poor scores for speech in quiet, they may benefit from an alternative amplification strategy, such as new hearing

aids, a boost in gain to their current hearing aids, or a frequency response that is better suited for their hearing loss. If a patient has low scores in speech in noise, they may benefit from speech in noise training such as clEAR-customized learning: Exercises for Aural Rehabilitation (Office of Research in Clinical Amplification-USA WS Audiology, n.d., 32:23, Clinical application). clEAR training consists of multiple games that train users in seven different areas that are critical to listening. These categories are auditory memory, auditory attention, phoneme discrimination, discourse comprehension, auditory processing speed, bound morpheme identification, and recognizing frequently used words (Crow, 2020). Instances where a patient shows poor context use may call for the patient to go through training on context and overall cognitive improvement. If the patient shows a high listening effort/ow tolerable time, they may find benefit in speech in noise training.

Author's Self-Test of the RRT

Upon the completion of my research into the RRT, I was provided with access to the test from Kuk. Below are figures 6 and 7, which display my P-I function and profile plot respectively.

Figure 6

Author's Self-Assessment P-I Function

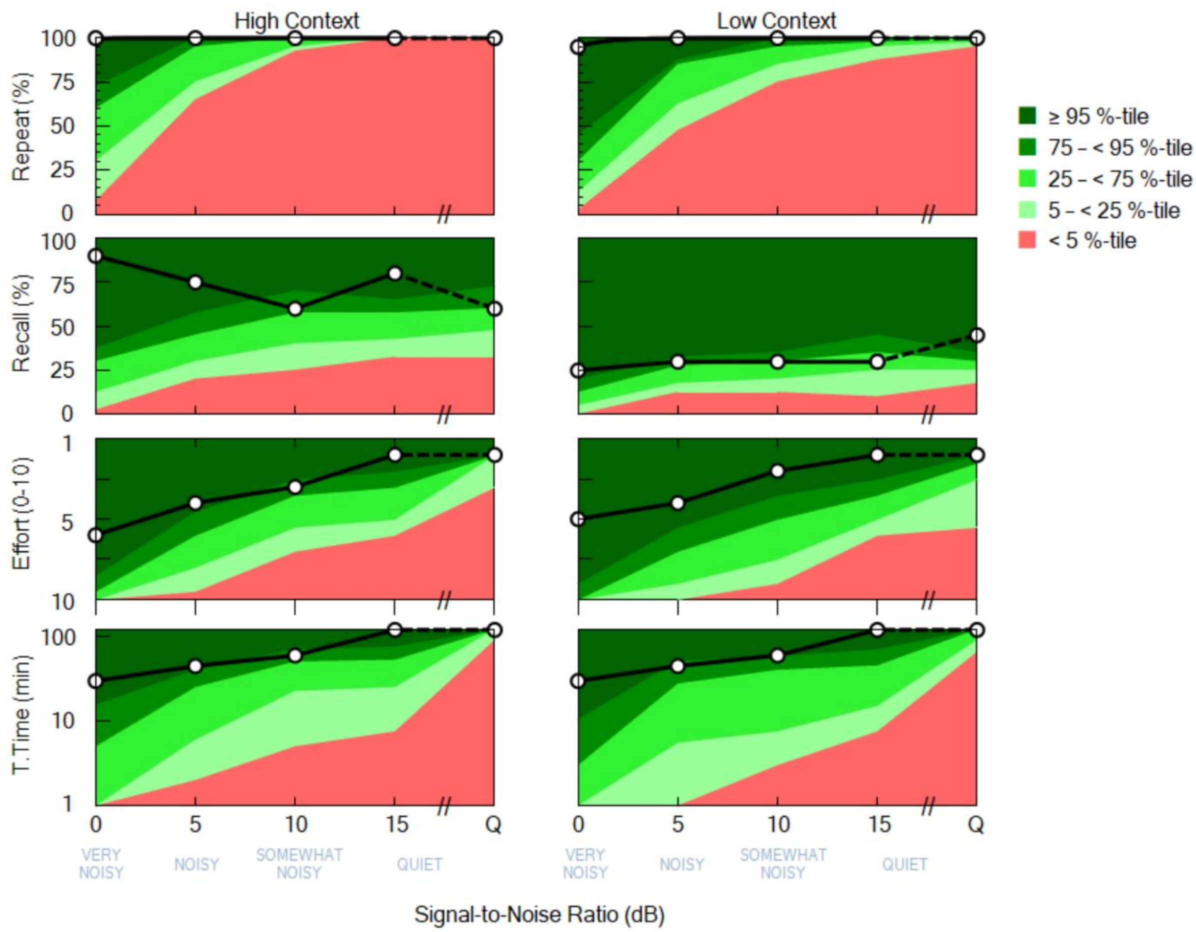
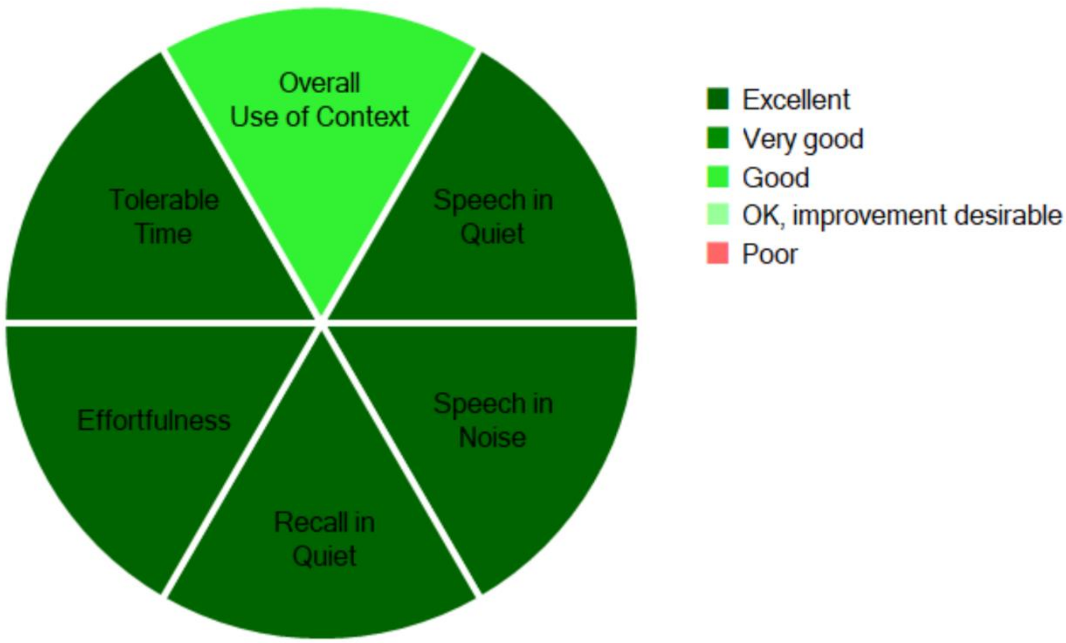


Figure 7

Author's Self-Assessment Profile Plot



Interpreting the results of my self-assessments from a clinical perspective, overall, no areas stand out as requiring intervention. My repeat, tolerable time, and effortfulness scores are greater than the seventy-five percentiles. One area that falls short is my recall scores, especially those in low context. My low context recall scores dip into the twenty-fifth to seventy-fifth percentiles, which does not indicate that I need to urgently attend to my recall ability, but it may be beneficial to stay mindful of this as I age. Examining the profile plot, all areas are displayed as "excellent," except for Overall Use of Context, which is displayed as "good." Similar to the P-I function, the profile plot suggests that I struggle most when context is low. It does not show that I need to take immediate action, but in the future, I may benefit from cognitive training.

Conclusion

The RRT will be useful to practicing audiologists. It can assess a patient’s repeat and recall abilities, tolerable time in a noisy situation, and their perceived effort. All of this is done at low and high contexts in an environment that is representative of realistic communication. There is no other audiologic test that can cover all the listed areas. By testing those aspects of communication, the RRT can be used to show audiologists in which areas their patients need intervention. Additionally, it takes 20-25 minutes to administer the RRT, which will be useful to audiologists with restrictive appointment timeframes. Currently, there is a small amount of literature that exists on the RRT. As more literature and research is published about the RRT, the test will become closer to getting accepted by practicing audiologists.

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