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Requirement Analysis for the Development of a Directed Exploration Virtual Reality Potentials Diagnosis System for Dyslexic Children

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ABSTRACT

Research shows that dyslexic children, who are generally stereotyped with learning disability, actually have unique potentials, especially in the visual spatial field. Thus, diagnosing their potentials is crucial to ensure that their educational needs can be fulfilled. Among the many technologies that could be used to develop such diagnosing tools, the non-immersive desktop virtual reality (VR) provides a simple but an effective solution. Premised on this backdrop, this study was carried out to analyze the essential requirements for developing a diagnosing tool that will help to diagnose the level of dyslexic children intelligence and their potentials in Malaysian context. The design principles to be analyzed were based on the directed exploration VR setting. A qualitative approach using on semi-structured interviews and observation techniques were used to elicit the relevant data. The respondents of the study comprised the president of Malaysian Dyslexia Association (MDA), a dyslexic teacher, and a dyslexic child who was attending an MDA intervention class. The findings of the study showed the dyslexic child was endowed with high intelligence and potentials in visual spatial field. Furthermore, both the MDA president and teacher emphasized the importance of a tool that could diagnose dyslexic children's potentials. Based on this emphasis, a non-immersive virtual reality web application could serve as a novel tool to diagnose dyslexic children's potentials in visual spatial field.

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INTRODUCTION

Research shows that dyslexic children, who are generally stereotyped with learning disability, actually have unique potentials, especially in the visual spatial (VS) field (Cooper, Ness, and Smith, 2004; Davis and Braun, 2010; Eide and Eide, 2011). More specifically, dyslexic individuals may have specific VS skills, namely the VS global processing (Von Karolyi, 2001). The finding of this specific skill among dyslexic children was based on two research conducted by Von Karoly and her colleagues (Von Karolyi, 2001; Winner, Von Karolyi, & Malinsky, 2000). This finding was further reinforced by a consensus reached in a special conference, which was held at the MIT Endicott House Conference Center, involving a discussion between dyslexic individuals and researchers (West, 2003).

According to Assouline and Lupkowski-shoplik (2012) and Committee (2012), diagnosing children's potentials is the first crucial step that has to be taken in order to identify and fulfill their educational needs. Researchers contend that early diagnoses of these children's potentials is vital because these children's potentials, once identified, can be further nurtured to attain its maximum impact in learning (Bacon and Bennett, 2013; Collinson and Penketh, 2010; Eide and Eide, 2011; Reis, Neu, and Mcguire, 2005). Furthermore, knowing their potentials in advance will help the children to plan their career paths more objectively by taking appropriate courses of study (Lubinski, 2010). Likewise, some researchers who have conducted research involving dyslexics, assert the same contention that existing education systems need to recognize dyslexic children's potentials in order to increase the children's intrinsic values. In addition, having known the children's inherent capability will enable the children's families or other members of the society to exert more effort to cater the children's learning, which was poorly overlooked previously (Cooper *et al*., 2004; Dee and Lafrance, 1997; Glazzard, 2010).

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In Malaysia, it is estimated that about 45,000 children between the age of five and six are dyslexic, and every five children out of 100 are likely to be dyslexic (Malaysia' s Ministry of Education, 2013). Thus, taking into account this sizeable proportion, the Ministry of Education (MOE) has launched an initiative that focuses on inclusive education through its strategic planning called *Pelan Strategik Interim KPM 2011-2020* (KPM, 2011). In this inclusive education initiative, the aim is to improve the learning of students of special needs by harnessing their potentials to the fullest, which will lead to a better, meaningful future. However, in the Malaysian context, the existing education system does not take into consideration the inherent skills, capabilities or potentials of the school children irrespective of their learning abilities (or disabilities). Thus, it is imperative that a mechanism is developed and used to assist the children with learning disability to diagnose their potentials from the outset of their learning process. Subsequently, relevant authorities or agencies can lend support to help accomplish the noble aim of the inclusive education in Malaysia.

The process of diagnosing children's potentials involves a number of phases, and in this regard psychometric testing tools can be used to aid the process. In keeping abreast with the rapidly changing technology, psychometric testing for Intelligence Quotient (IQ) test, potentials, or aptitude has undergone similar changes, notably by being web-based or online. However, most of the websites that offer these tests use two dimensional (2D) format and target general users only. This format is not only less effective but inaccurate due to the limitations inherent in 2D format, which lacks interactivity and depth. To overcome this limitation, several researchers have proposed virtual reality (VR) as a tool for psychometric testing (Cohen and Hegarty, 2012; Hartman, Connolly, Gilger, Bertoline, and Heisler, 2005; Mestre and Vercher, 2011). In addition, Cohen and Hegarty (2012) recommend the development of a online system based on VR technology that is suitable to psychometric testing involving children.

Previously, VR technology was associated with a expensive collection of high-tech gears and gadgetry that immerses a user into a synthetic environment. Today's VR technology ranges from expensive to affordable system, which can be categorized in three categories that are determined by the level of immersion, namely immersive, semi-immersive, and non-immersive VR systems. The third VR category, which runs on the desktop platform (thus, named desktop VR) has featured prominently in many fields such as medical (Haworth & Baljko, 2012; Stankiewicz, Cassandra, Mccabe, and Weathers, 2007; Vinson, Lapointe, Parush, & Roberts, 2012), education (Ausburn, Martens, Washington, Steele, and Washburn, 2009; Daghestani, Ward, Xu, and Al-Nuaim, 2008; Kovárová andSokolský, 2011; Rahim *et al*., 2012; Steele, Fulbright, and Nichols, 2010), business (Nassiri, 2009), training (Samsudin, Rafi, Mohd Ali, & Rashid, 2014; Wang and Li, 2004), and cognitive scientific research All these successful applications of desktop VR indicates that non-immersive VR is a practical, affordable and effective technology that can be applied to psychometric testing of dyslexic children.

Against the backdrop of the earlier discussion, the authors carried out an initial study based on semi-structured interviews and observations involving a small group of interviewees, consisting of the president of Malaysian Dyslexia Association (MDA), a dyslexic teacher, and a dyslexic child. The findings of this initial study, as part of a larger research, would help in conceptualizing the framework of a diagnosing tool to be used at the later stage. To guide the research, several research objectives were formulated as follows:

i) to identify a dyslexic child's intelligence,
ii) to identify dyslexic child's potentials,
iii) to investigate the dyslexic child's perception of the development of a proposed system,
iv) to identify the appropriate system design of the proposed system.

Addressing the the above research objectives entail the following research questions as follows:

i) What is the intelligence level of the dyslexic child?
ii) What is the dyslexic child's potentials?
iii) What are the interviewees' perceptions of the development of the proposed system?
iv) What is the suitable design of the proposed system?

MATERIALS AND METHODS

This research used a qualitative approach to answer the research questions, which involved semi structured interviews and observations to collect the relevant data.

Participants:

In this research, the purposive sampling technique was employed whereby members and pupils of the Malaysian Dyslexia Association (MDA) were selected. According to Johnson and Christense (2012), this technique is suitable to use when the research involves a population that has unique characteristics such as dyslexia children. For the interview session, the president of MDA, the coordinator of MDA, and a pupil (who was attending the intervention class) were recruited. For the observation session, a group of pupils at the MDA center was selected.

Instruments:

To elicit the relevant data, two sets of semi structured questions were drafted. The first set consists of four main sections, where each section deals with the relevant research question. This set was used during the interview session involving the the president and the coordinator of MDA. The second set consists of questions that explores the interest and potentials of the dyslexic child, and his perception of the system design. Both sets were prepared based on the principles recommended by Johnson and Christense (2012). The questions were later reviewed and revised by the researchers in order to ensure they are clear and concise.

Procedure:

The interviews and observations were carried out based on the guidelines provided by Johnson and Christense 2012), and the research procedure involved three phases;

Phase I:

The president and coordinator of MDA were interviewed through semi-structured protocol, where oral responses to the questions were recorded and then transcribed accordingly. All the interviewing sessions lasted not more than an hour.

Phase II:

A group consisting of five pupils was observed for 30 minutes, where a set of *Lego* was given for them to build any objects that came across their minds.

Phase III:

Based from the observation, a pupil who had shown strong potentials in VS was chosen for the interview session. The interview with this child lasted for half an hour. In addition, his work, scrap book, and origami of objects were examined.

Results:

Table 1 shows the demographic of the interviewees, namely the president, the coordinator and the selected pupil. The president and coordinator have working experiences with dyslexic children for more than 20 and 10 years, respectively. The third respondent was a 12 year-old child, who was attending the intervention class at the MDA for the last three months.

Table 1: Respondents' profile.

Respondent:	1	2	3
Psuedo name	Noor Aini	Aminah	Ahmad
Designation	President	Coordinator/teacher	Dyslexic child
Gender	Female	Female	Male
Age	63 yrs	44 yrs	12 yrs
Working experience with dyslexic children	>20yrs	>10yrs	-

Table 2 summarizes results of the first and second research questions, where the first respondent (i.e., the president) and second respondent (i.e., the coordinator) agreed that dyslexic children were also endowed with high intelligence and potentials despite the latter' learning disability. Revealingly, the first respondent gave a very positive comment regarding the dyslexic intelligence where she said "They are very smart and also speak very well and have the courage to speak for themselves as well for others. They have good critical thinking and vivid imagination". Then, she related her experience dealing with a 10-year old dyslexic child who could repair a computer by just looking at others doing the work. The second respondent, who is the teacher as well the coordinator, stated that dyslexic children may possess different levels of intelligence. She also claimed that there was about 20 to 30 percent of dyslexic children who have high intelligence and potentials. According to her, the children's salient traits could be observed when they were involved in certain activities such as drawing, building Lego blocks, and sports; however, these children were not skillful in fine art. Both respondents indicated that the children's potentials became apparent to them during recess-time, center, ant classrooms activities.

Table 2: Level of intelligence and potentials of dyslexic children.

Question	Respondent		Supportive Data Resources
What is the intelligence level of your dyslexic pupils?	R1	R2	
i. High	✓		1
ii. Average			0
iii. Low			0
iv. Various (low to high)		✓	1

Do you realize that your dyslexic pupils have innate potentials?			
i. Yes	✓	✓	2
ii. No			0
During which activities that their potentialss become apparent to you?			
i. Recess time activities	✓	✓	2
ii. Center activities	✓	✓	2
iii. Classroom activities		✓	1
Do they show any interest or potentialss in any specific area such drawing, building Lego, creating things etc?			
i. Drawing	✓	✓	2
ii. Building Lego	✓	✓	2
iii. Story Telling	✓		1
iv. Sporting		✓	1

From the observation of a pupil named Ahmad, this boy demonstrated a remarkable skill in building a car model and a helicopter model. In addition, an inspection of his work revealed that he had built numerous creative origamis. Likewise, similar creative works were observed in his scrap book, indicating his creative capability.

This creative capability of his was made more tenable by the MDA coordinator (who was his teacher), professing that Ahmad was an intelligent boy who has potentials and interest in VS field. Later in an interview, Ahmad expressed his ambition to become an architect or a sportsman.

Table 3 summarizes the findings pertaining to the third research question. Both respondents stated that the current curriculum did not take dyslexic children's potentialss into consideration. They strongly agreed that children's potentials should deserve greater attention to enable it to grow into a well-developed skill or talent, thus boosting children's self esteem. For the development of a system to diagnose potentials, they strongly opined that such a system could help them manage dyslexic children's learning more effectively.

Table 3: Respondents' perception of the proposed system

Question	Respondent		Supportive Data Resources
Does the current curriculum consider dyslexic children's potentials into consideration?	R1	R2	
i. Yes			0
ii. No	✓	✓	2
Do you agree that dyslexic children's potentials should be identified and developed further?			
i. Yes	✓	✓	2
ii. No			0
If you agree to the previous immediate question, why did you take such a stand?			
i. To allow the children to realize their own giftedness	✓	✓	2
ii. To allow the children to increase their self esteem	✓	✓	2
Is there any current mechanism to diagnose such potentials?			
i. Yes			0
ii. No	✓	✓	2
Do you agree that such a system needs to be developed to diagnose dyslexic children's potentials?			
i. Yes	✓	✓	2
ii. No			0

To get an overall view of the proposed system, all the three respondents were interviewed. Table 4 summarizes the respondents' opinions of the proposed system. For the type of system deemed suitable, they believed virtual reality was an appropriate technology, preferably based on the computer game genre. As for the setting, all respondents suggested using an outdoor environment. Interestingly, one respondent also suggested using a home or a school environment. They all agreed that such a system should contain elements to instill creativity and motivation. In addition, one respondent also suggested using explorative element in the system.

Table 4: Recommendations of the proposed system design.

Question	Respondent			Supportive Data Resources
What will be the type of technology that is suitable for diagnosing dyslexic students' potentials?	R1	R2	R3	
i. Two dimensional multimedia				0
ii. Three dimensional multimedia				0
iii. Virtual Reality	✓	✓	✓	3
What will be the appropriate computer environment to be used by dyslexic students?				
i. An outdoor environment – playground/theme park	✓	✓	✓	3
ii. A home environment		✓		1
iii. A school environment		✓		1

What will be the elements of the computer environment deemed important?				
iv. Creativity	✓	✓	✓	3
v. Motivation	✓	✓	✓	3
vi. Exploration			✓	1
Could the pilot testing of the proposed prototype involve your pupils?				
i. Yes	✓	✓	✓	3
ii. No				0

Discussion:

Research findings show that children with dyslexia, irrespective of their learning disability, do have exceptional intelligence and potentials. More profoundly, a dyslexic child who manifests these characteristic is named as twice exceptionality (Nicpon, Allmon, Sieck, & Stinson, 2010; Montgomery, 2009). In this study, the opinion

of the coordinator stating that there is about 20-30 percent of dyslexic children at the MDA center who have exceptional intelligence seems to concurs with a similar study carried out by Silverman (2003) and Montgomery (2009). According to these researchers, dyslexic children form the prominent group that has twice exceptionality compared to other student groups, where about 10 percent of the former students have exceptional IQ test scores exceeding 120 points. Moreover, the MDA president's assertion that dyslexic children are endowed with intelligent mind, creative skills, and vivid imagination runs parallel with other previous findings (Davis & Braun, 1997, 2010; Eide & Eide, 2011; Marazzi, 2011).

With regard to VS skills, neuroscience researchers assert that individuals with high VS skill will manifest this ability when processing location, movement, and spatial transformation of objects, and these individuals will usually pursue professions in science, technology, engineering, and mathematics (STEM). Furthermore, their spatial proficiency is different from individuals who pursue carreers in visual arts. In these art professions, the majority of the practitioners has good verbal skill and imagination (Blazhenkova & Kozhevnikov, 2010; Kozhevnikov, Blazhenkova, & Becker, 2010; Mann, 2005; Motes, Malach, & Kozhevnikov, 2008). Moreover, the MDA coordinator also asserted that dyslexic children are not very good in fine art despite their enthusiasm in such activities, which concurs with Eide and Eide's contention (2011) . Premised on the above findings, the child respondent (i.e., Ahmad) in this study seems to possess high VS skill. This finding is in congruent with other research findings (Bacon & Bennett, 2013; Bacon, Handley, & McDonald, 2007; Cooper *et al*., 2004; Von Karolyi, 2001) that dyslexic individuals do possess exceptional VS skill.

With regard to current practice of the implementation of the curriculum, the first and second respondents asserted that dyslexic children's potentials were not being given due consideration, which could be detrimental to their self esteem. These respondents also cautioned the impact of this detriment on children's self-esteem, particularly on those who are in the intervention program. Typically, these children will be placed in a special separate class in their school due to the misguided assumptions that they are less intelligent than others. In such a setting, these children will experience some form of segregation, negative stereotyping, and mistreatment, making their school lives unpleasant and lackluster. Ultimately, their self-esteem will suffer when this situation is allowed to prolong. Likewise, a similar caution was expressed by Ingesson (2007) who states that the first six years of school life subjects dyslexic children to several challenges, which could affect their self esteem. Without any kind of concrete interventions, they would succumb to despair and failure (Eide & Eide, 2011). To avoid this bleak outcome, the respondents emphasized that these students need to be assured that they have potentials or skills that are unique, thus making them feel assured and appreciated. Having realized that their abilities are acknowledged by ther teachers and peers, dyslexic students' intrinsic motivation would increase.

(Glazzard, 2010; Munro, 2002; Ruban and Reis, 2004). To attain this positive reinforcement, a positive, conducive environment is entailed to help these children develop their potentials to the fullest, which would lead to better learning and promising future (Armstrong, 2012; Davis & Braun, 1997, 2010; Eide & Eide, 2011).

In addition, Gagne (2009) points out that every child' potential should be tapped and nurtured through formal or informal education such that this individual would later become highly talented or skilful.

In view of the lack of diagnosing systems or tools in Malaysia, both respondents expressed their strong enthusiasm for such a system. They wished that such a system could be utilized as an online tool to screen dyslexic children's potentials throughout Malaysia. The screening process would help indentify the inherent potentials of the children, thus enabling instructors or teachers to plan appropriate teaching strategies that are aligned with the identified potentials. In the long run, these students could pursue meaningful,appropriate academic programs or courses based on their abilities, which could be harnessed in the right manner.

For the type of a computer environment for the diagnosing tool, the respondents preferred a mini game application using virtual reality (VR) rather than using 2D or 3D multimedia technology. Their preference is not surprising given the specific demographic of the intended users – children of ages between 10 and 12 years. From the technical standpoint, VR offers several features that are not only appealing but educational such as real-time nagivation, interaction, multi-perspective viewing, animation, and multi-modal. As for theme of the application, all respondents preferred an outdoor environment to a home or a school environment. Furthermore,

the third respondent (i.e., the dyslexic child) expressed his strong interest for an environment that is explorative and challenging. His interest in such an environment reflects the general traits of dyslexic children who love adventure and challenges (Davis & Braun, 1997, 2010; Eide & Eide, 2011; Marazzi, 2011; West, 2003). The first two respondents also emphasized a vibrant, creative environment to capitalize on the inate abilities of dyslexic children, which are vivacious and creative (Collinson & Penketh, 2010; Davis & Braun, 1997, 2010; Eide & Eide, 2011; Marazzi, 2011). Lastly, motivational element, such as rewarding or reinforcement gestures or feedback, should be embedded into the system to motivate the children to use the application with greater ease and enjoyment. The need for such a feature is highly recommended by Nor Hasbiah (2007) who found that dyslexic children were motivated to use such a similar application when their inputs were acknowledged through rewarding messages.

Based on the synthesis of the literature review of existing research, the authors propose a system called *Directed Exploration Virtual Reality Potentials Diagnosis System* (DEVRPS) as a tool to diagnose dyslexic children's VS potentials. The conceptual framework that will be used to develop this system is shown in Figure 1.

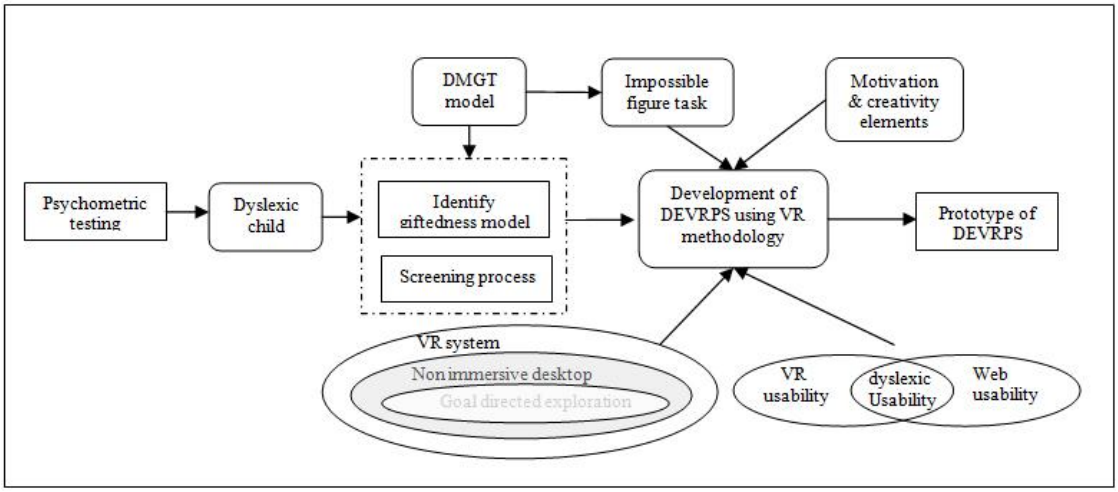

Fig. 1: Conceptual Framework of the development DEVRPS.

For the proposed system, there are several talent models that could be used to guide its development such as Gagne's Differentiated Model of Giftness and Talent (DMGT), Sea Star model, and Multiple Intelligence Theory. However, the DMGT was chosen in view of its high relevancy to dyslexic children. According to the DMGT model, one of the potentials that could be developed to become a talent is the VS skill (Gagne, 2009). Moreover, the literature is replete with findings that suggest many dyslexic individuals are highly-endowed with this skill, thus reinforcing the application of the DMGT model to the development of DEVSPS. To assess dyslexic children's VS potentials, an instrument based on impossible figure task will be deployed in the system. The choice of the impossible figure task is appropriate because research has shown that this type of task can diagnose dyslexic childrens' potentials with greater accuracy and reliablility (Chan, 2009; Von Karolyi, Winner, Gray, & Sherman, 2003)

Given the main objective of the proposed system is to assist the diagnosis of potential of every dyslexic child in Malaysian, it is therefor essential that everyone can gain access to this tool. In addition, the design of the system should engender user experience that is enjoyable, easy to use, and entertaining. Likewise, the development of such a system should also be viable in terms of cost and maintenance. The technology that fits these needs is the non immersive VR, which runs on the desktop platform. To create an interesting and challenging environment, the system would use several methodologies or principles, namely the VR methodology, directed exploration VR principles and web usability principles that are deemed appropriate to dyslexic children.

Conclusion:

Every pupil should have the opportunity to experience meaningful learning in order to gain relevant knowledge and acquire skills, irrespective of their background. However, in Malaysia, some groups of the student population seem to have missed these experiences due to a lack of focus on their learning needs. For example, dyslexic children's learning needs, which are influenced by their innate talent or potentials, are not properly addressed. One of the reasons for this lack of attention is that the current system of the Malaysian educational system does not take these children's potentials into consideration when the curriculum are

developed and implemented. The system only emphasizes intervention programs to address their learning problems without focusing on the core of the learning issues – dyslexic children's potentials. As a result, these dyslexic children will develop low self-esteem because they will be generally viewed to be academically poor or weak, which can lead to other problems such as poor discipline, low attendance rates, and others. In view of these academic risks, dyslexic children's potentials must be identified from the outset of their learning to help tailor proper teaching methods by their teachers and to help them choose proper courses that are aligned with their potentials.

In the MOE's *Pelan Strategik Interim KPM 2011-2020*, the need to improve special needs students' achievements based on their individual potentials has been prioritized to help them gain a better and meaningful life. However, this plan does not include the necessary process to diagnose their potentials. Hence, by developing the DEVRPS system, a novel tool can be used by the relevant authorities (which oversee and manage dyslexic children) to diagnose dyslexic children's potentials prior to planning the appropriate course of actions for these children learning. More specifically, this system will be developed to identify the specific potentials of dyslexic children – the visual spatial potential. The ensure an effective, efficient development of this system, several principles will be used such as the VR methodology, and web usability principles.

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