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## Developing Bilateral and Spatial Concepts in Primary School-aged Children: An Empirical Evaluation of the Anker Bilateral Spatial System

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# Developing Bilateral and Spatial Concepts in Primary School-aged Children: An Empirical Evaluation of the Anker Bilateral Spatial System

## Abstract

**Background:** Visual-spatial and visual-motor perceptual difficulties contribute to school-aged learning problems. Hence, a need exists to address children's visual-spatial and visual-motor perceptual difficulties as early as possible in the child's school career. Thus, this study reports on the evaluation of the Anker Bilateral Spatial System's (ABSS) effectiveness in remediating primary school children's perceptual difficulties.

**Method:** Thirty-one children (17 boys and 14 girls) aged 6 to 12 years who had been identified by their classroom teacher as having observable visual-spatial and visual-motor perceptual difficulties participated in a 10-week pre/posttest intervention study. The study's pre/posttest assessments included the Developmental Test of Visual-Motor Integration (VMI), the Spatial Awareness Skills Program Test (SASP), and two subscales of the School Function Assessment (SFA).

**Results:** Paired t-test statistics were calculated on the pre/post intervention scores. Paired t-test statistics calculated ( $p = .05$ ) that significant change had occurred in the writing speed ( $t = -3.978, p < .001$ ).

**Conclusion:** Given that the study's Year 1 students made progress in more areas of remediation than did any other year level, it is evident that the ABSS is particularly effective with this year group.

## Comments

Dr. Janet Richmond is currently a lecturer at Edith Cowan University in occupational therapy in the School of Exercise and Health Sciences. Dr. Richmond's research interests are visual-perceptual development, intervention and remediation in children and adults, attention and cognitive disorders, and aging and disability. She has published two book chapters and additional articles related to her areas of research.

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Ms. Sarah Evans is an occupational therapist who has been working in pediatrics for seven years. She works mostly with primary school children and is passionate about helping each child reach their potential. Ms. Evans understands the importance of evidence-based practice and fervently supports research that may benefit her clients.

## Keywords

Spatial concepts, bilateral integration, writing, children, learning

## Cover Page Footnote

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The origins of visual-spatial and visual-motor perceptual difficulties have been linked in newborns to very preterm low birth weights (Geldof, van Wassenae, de Kieviet, Kok, & Oosterlaan, 2012) and to the incomplete inhibition of the Asymmetrical Tonic Neck Reflex (ATNR) during the first year of infant life (Taylor, Houghton, & Chapman, 2004). Moreover, these suboptimal postpartum occurrences are thought to contribute to the emergence of visual-spatial perceptual difficulties during preschool and continue into the primary school years. Upon attending kindergarten, visual-spatial and visual-motor perceptual difficulties typically manifest as a range of learning problems, such as difficulty crossing the visual midline, a poor understanding of directionality, difficulty identifying left from right and applying this laterality concept to a range of physical objects (including body parts and printed text), and difficulty moving fluidly (Cheung, Poon, Leung, & Wong, 2005; Kirk, Gallagher, & Anastasiow, 2000; Oliver, Dale, & Plomin, 2007; Silver, 2001).

In turn, primary school children with poor visual-spatial and visual-motor difficulties usually have problems with judging heights and distances, grasping the meaning of spatial-related words, identifying the orientation of certain letters and numbers, recognizing shapes in instances where their spatial orientation has been altered, writing legibly, learning to read, and arranging and computing columns of numbers (Cheung et al., 2005). The eventual cumulative effect of these difficulties is typically a level of scholastic dysfunction that is so significant that it impedes

academic progress throughout not only the primary but also the senior school years (Case-Smith, 2002; Klein, Guiltner, Sollereeder, & Cui, 2011; Sigmundsson & Hopkins, 2005).

Consequently, unaddressed visual-spatial and visual-motor perceptual difficulties in the primary school years can place a considerable financial burden on parents, schools, and society with regard to providing postprimary school remedial interventions (Decker, Englund, Carboni, & Brooks, 2011; Frostig, Lefever, & Whittlesey, 1966).

Furthermore, given the range of and complexities associated with visual-spatial and visual-motor perceptual difficulties, it is not surprising that poor perceptual indicators are used as diagnostic symptoms for a number of childhood conditions, including but not limited to, dyslexia, attention-deficit/hyperactivity disorder, William's syndrome, down syndrome, autism, spina bifida, and cerebral palsy (Burtner, Dukeminier, Ben, Qualls, & Scott, 2006). Hence, it is imperative to evaluate programs that purport to effectively remediate visual-spatial and visual-motor perceptual difficulties in the early-learning primary school years. To this end, this paper evaluates the Anker Bilateral Spatial System (ABSS).

### **Visual-Spatial Perceptual Difficulties**

Visual perception is the capacity of the higher levels of the central nervous system to recognize, understand, interpret, and give meaning to what is seen (Gardner, 1996). Visual-spatial perception encompasses the ability to perceive or otherwise react to the size, distance, or depth

aspects of the environment (Chan, 2010). In addition, it is acknowledged that visual perception can be stimulus driven or goal driven. In this context, stimulus-driven visual perception is the dynamic process of receiving the environment through sensory impulses and translating those sensory inputs into meaning based on previously developed understandings of the physical environment (Humphreys, Riddoch, Forti, & Ackroyd, 2004). In contrast, goal-driven visual perception occurs when the perceiver cognitively focuses attention on a current innate perceptual goal (Humphreys et al., 2004).

### **Visual-Motor Difficulties**

Visual-motor skills are increasingly assessed as a component of psycho-educational assessment to measure foundation skills required for academic learning (Decker et al., 2011). Visual-motor skills, including bilateral-motor integration and visual-motor integration, influence the development of handwriting and academic achievement (Catts & Kamhi, 2005; Feder & Majnemer, 2007; Oliver et al., 2007), and as such are important in school children's development. Visual-motor skills develop early in a child's life when they begin to manipulate objects and continue on to scribbling, drawing, and writing (Feder & Majnemer, 2007). In addition, research has identified a link between visual-motor skills and perception in the learning process (Feder & Majnemer, 2007; Humphreys et al., 2004).

The impact of visual-spatial and visual-motor perceptual difficulties on both scholastic and life-course development is understood to be far reaching, as such difficulties impinge on many

aspects of occupational performance (Hanneford, 2005; Taylor et al., 2004). Indeed, previous research in this field has focused on determining the link between spatial orientation and the bilateral concepts that influence learning (Frostig et al., 1966; Kamhi & Catts, 2011). The findings from this body of research suggest that people who have difficulty performing sequential spatial tasks and identifying spatial orientation tend also to have difficulty reading and performing other structured academic tasks that involve the sequencing or the spatial orientation of objects (Decker et al., 2011; Massengill & Sundberg, 2006; Richmond & Holland, 2010). Spatial-perceptual skills are required not only for reading literacy, but also for geometry and other mathematical computations (Chan, 2010; Chinn, 2002; Decker et al., 2011).

Current primary school methods of remediating visual-spatial and visual-motor perceptual difficulties are based on historical theory and generally involve eye exercises, two dimensional board games, and gross motor activities that require children to position themselves in relation to another object or specific task-orientated practice (Ayres, 1978; Feder & Majnemer, 2007; Howe, Roston, Sheu, & Hinojosa, 2013; Jordan, 1990). Such games commonly necessitate the child to reconstruct or build a pictorial design using colored shapes on a two dimensional surface. Other interventions include repetition and left-right laterality training, as well as two-dimensional computer games that involve manipulating a computer mouse or utilizing the keyboard's directional arrow keys

(Murphy & Spencer, 2009). There are very few manipulative or electronic games with which a child can become physically involved in manipulating game shapes or building shapes in a three-dimensional level while simultaneously developing their depth and spatial perception. This lack of a comprehensive visual-spatial and visual-motor remediation program led to the development of the ABSS (see Figures 1 and 2).



*Figure 1.* The Anker Bilateral Spatial System. A bilateral board, an arc representing the intervention space, geometric shapes, and marbles of varying size allow players to manipulate designs in a two or three dimensional plane.



*Figure 2.* The Anker Bilateral Spatial System board. Transparent shapes are manipulated into a design in either a two or three dimensional plane within the parameters of the board.

To date, the provision of assistance for people with visual-spatial and visual-motor perceptual difficulties has received little research attention other than that related to handwriting, despite the existence of a sizeable body of evidence that links visual-spatial difficulties and classroom performance (Erhardt & Meade, 2005; Feder & Majnemer, 2007; Howe et al., 2013; Tsai, Wilson, & Wu, 2008). While anecdotal practice evidence suggests the ABSS is effective in improving visual perception and bilateral integration, the ABSS has not been empirically evaluated. Therefore, this paper aims to contribute to the present understanding of primary students' visual-spatial perceptual difficulties and their remediation by determining if the ABSS is, or is not, an effective therapy tool in developing bilateral and spatial skills in primary school-aged children. Specifically, the research questions are as follows:

- Will regular use of the ABSS improve the development of bilateral integration and spatial skills in primary school children?
- Will the development of spatial skills and bilateral integration reduce the occurrence of letter and number reversals in writing and reading?
- Will regular use of the ABSS improve spatial skill more than the normal classroom teaching processes to which all children are exposed?

## Methods

Pre-/posttest designs are commonly used in the evaluation of educational programs that require the measurement of the change that occurs

in children's abilities following their engagement in an experimental treatment program (Christensen, Johnson, & Turner, 2011). Hence, the present study's evaluation of the ABSS adopted a single group pre-/posttest research design. The pretest assessment took place prior to the intervention and the posttest assessment took place after the completion of the ABSS program's 10 intervention sessions. A within-participants design was considered appropriate for measuring change over time to determine the application benefits of the intervention (Christensen et al., 2011; Portney & Watkins, 2000), for decreasing threats to the intervention's internal validity (Christensen et al., 2011; Portney & Watkins, 2000), and for meeting the ethical beneficence requirement of providing all participants with equivalent access to the intervention.

### **Participants**

The original sample was comprised of 34 children who had been identified by their classroom teachers as having visual-spatial and visual-motor perceptual difficulties. Eligibility criteria included children aged 6 to 12 years who have difficulty producing neat writing, a tendency to reverse letters and numbers, find writing on lines difficult, are unable to space words and mathematical computations correctly, confuse left and right, or have any other spatial or bilateral integration difficulties. All of the children were recruited from three private primary schools located in the northern suburbs of Perth, Western Australia. The researchers excluded any child who lacked the cognitive capacity to attempt the ABSS activities (diagnosed moderate to severe

intellectual disability), or who had such severe muscular-skeletal impairments that they were unable to engage physically in the required ABSS visual-motor control activities as identified by the researcher. Other exclusion criteria included children receiving occupational therapy concurrently to the research time frame; however, the study did include those on a waiting list for therapy. One child had previously received occupational therapy. None of the children were identified as receiving other services during the project. Given that all of the participating children resided in the suburbs of similar middle socioeconomic advantage, had undertaken the same preprimary and primary education programs, and were predominantly (84% [n = 26]) right-handed, the sample was considered to be homogenous. The researchers concluded, therefore, that it was reasonable to expect the children in the study group to exhibit a similar reaction to the ABSS treatment intervention.

The original sample comprised 34 children (20 boys and 14 girls) who were aged 6 to 12 years (mean age 7.38 years). Three children did not complete the program and therefore were not included in the final sample of 31 participants (17 boys and 14 girls). Twelve of the participants were in Year 1, ten were in Year 2, six were in Year 3, and three were in Year 5.

### **Procedure**

Prior to the commencement of the study, the researchers secured ethics approval from the administering institution's Human Research Ethics Committee (HREC). The participants were recruited to the study through the auspices of three

private primary schools. The school's principal in each case encouraged their classroom teachers to identify students in their classes who were exhibiting spatial-perceptual and/or bilateral integration difficulties. After identifying the students in this manner, the schools' principals contacted the parents of the identified children to request consent for their child to participate in the study. All of the parents approached in this manner gave written consent for their child's involvement in the study. A third of the children (i.e., 10 participants) were asked to wait until the following school term for their involvement. This staged delivery of the ABSS was necessitated due to school timetabling requirements that limited the available time that students could be away from their class activity. All pre-/posttest assessments and intervention sessions were conducted at the premises of a private occupational therapy practice or at the children's own school. Each session lasted 30 minutes.

### **Pre-/posttest Assessment Materials**

The study's pre-/posttest assessments were each comprised of the Developmental Test of Visual-Motor Integration (VMI) (Beery & Beery, 2004); the Spatial Awareness Skills Program Test (SASP) (Rosner, 1973); and the material use, writing subscales of the School Function Assessment (SFA) (Coster, Deeney, Haltiwanger, & Haley, 1998). Fine-motor speed was measured by the children's speed of placing pegs in a board. These tests are routinely used in educational settings to assess the need for, or success of, an intervention, since they report high inter-rater reliability, stable test-retest reliability, adequate

face validity, and good content validity (theory base, assessment by experts, and Rasch or item analysis of contents). In addition, these assessments claim clinical utility and sensitivity to change in relation to chronological age or developmental level of the norming group.

### **Intervention**

ABSS is a client-driven intervention that assists with the remediation of perceptual and bilateral integration difficulties through enhancing children's understanding of the space beyond the initial visual plane as well as the symmetry of objects that are found within nature (e.g., on the human body) (Hillstrom, Wakefield, & Scholey, 2013; Schiano, McBeath, & Chambers, 2008). In this regard, the ABSS is comprised of a bilateral board, an arc representing the intervention space, 24 geometric shapes, 25 marbles of varying size, a pointer, a cylinder, stoppers, a number of toys to demonstrate symmetry, and a manual with examples of how the shapes are manipulated to build designs in a two or three dimensional plane. The players manipulate shapes into a series of designs in either a two or three dimensional plane within the parameters of the board. To view a video demonstration of the ABSS, visit [https://www.facebook.com/photo.php?v=529759943800839&set=vb.523607477749419&type=3&video\\_source=pages\\_video\\_set](https://www.facebook.com/photo.php?v=529759943800839&set=vb.523607477749419&type=3&video_source=pages_video_set).

The ABSS's shapes are made of a transparent material, thus making it possible for children to visualize and demonstrate space beyond the initial plane and for the therapist to demonstrate to players a number of pathways that lead from the foreground to the background of the



ABSS designs. As the designs can be individualized, the therapist can make adaptations to the ABSS in order to make it easier to grasp the concepts being taught. In addition, the design of the ABSS board encourages the bilateral involvement of the player through the use of both hands and through the mirroring of designs on both the left and right side of the board. During the intervention period, children use the ABSS to create a variety of designs using a set number of shapes. Examples of designs used include a basic person to a complex building with multiple shapes and toys. Integral to the ABSS is the concept that the board represents space and that many objects in space are symmetrical around an axis. Hence, by working with the shapes within the parameters of the board's spatial confines, the program aims for improvements in the users' spatial concepts and bilateral awareness through eliciting adaptive responses in their performance. In doing so, the ABSS encourages development of both the stimulus and the goal-driven visual perceptual components of the central nervous system. Users are guided through the construction of designs by photographic examples, and are encouraged to develop their own designs (Chan, 2010; Humphreys et al., 2004).

### **Treatment Regimen**

The children participated in the study's ABSS activities over the course of 10 therapy sessions which took place over a 10 week period in one 12 week school term. Therapy session times were set in consultation with and consideration of each school and each family's needs, as well as the intervention's maintenance

need for consistent session times. The pretest intervention measures were conducted in the first week of the school term and the posttest intervention measures were administered in the last week of the term, thus allowing each child in the 10 intervening weeks to have one weekly ABSS session. As the ABSS is individualized, the sessions were adapted to meet each child's needs, age, and their tolerance of the activities. The chief investigator trained the therapists administering the ABSS (i.e., two experienced paediatric occupational therapists in private practice) in its application and provided them with debriefing sessions after the initial session, after the third intervention session, and after the ninth session. These debriefing sessions allowed the chief investigator to ensure consistent application of the assessments and the ABSS program across therapists.

### **Data Analysis**

The outcomes of the ABSS intervention posttest assessments were compared to the outcomes from the pretest assessment. Scores obtained on the VMI, SASP, and SFA subscales were recorded on two separate occasions: at initial pretest (one week prior to intervention) and at posttest (one week post the 10 intervention sessions). Differences in scores were analyzed with the software Statistical Package for the Social Sciences (SPSS-19), using a single factor repeated measures analysis of variance and the Tukey test for honest significant difference (Portney & Watkins, 2000).

## Results

Paired t-test statistics were calculated on the pre-/post score data with the alpha set at .05. These indicated a significant change in writing speed ( $t = -3.978$ ,  $p < .001$ ), material use (bilateral measure) ( $t = -.449$ ,  $p < .001$ ), spatial perception ( $t = -8.408$ ,  $p < .001$ ), and peg test (dominant hand  $t = -2.800$ ,  $p = .011$ ; non-dominant hand  $t = -3.491$ ,  $p = .002$ ). When the participants' results were split into two groups (the second term and third term group) for analysis, the second term group displayed significant change in writing speed ( $t = -3.272$ ,  $p = .003$ ), material use ( $t = -8.178$ ,  $p < .001$ ), spatial perception ( $t = -7.319$ ,  $p < .001$ ), and peg test non-dominant hand ( $t = -3.197$ ,  $p < .001$ ). The third term group participants displayed significant change in writing speed ( $t = -8.253$ ,  $p = .027$ ) and spatial perception ( $t = -3.274$ ,  $p = .014$ ) after the non-

treatment period. After this group participated in the ABSS treatment for the 10 sessions, they displayed a significant change in material (bilateral) use ( $t = -2.791$ ,  $p = .027$ ). In the overall program, the third term participant group displayed significant improvement in writing speed ( $t = -2.431$ ,  $p = .045$ ), material use ( $t = -4.439$ ,  $p = .003$ ), and spatial perception ( $t = -4.461$ ,  $p = .003$ ).

Year 1 through Year 3 students made significant progress in material use and spatial perception, while Year 1 students also made significant progress in writing speed and peg test non-dominant hand. Year 2 students made additional significant progress in visual-motor integration and Year 5 students made significant progress in spatial perception and peg test non-dominant hand only (Table 1).

**Table 1**

*ABSS T-Test Results for Year Level Outcomes*

Year level	Construct pre-post	t-test	Significance (2-tailed)
1	Writing speed	-5.778	.000
1	Material use	-6.952	.000
1	Spatial perception	-5.874	.000
1	Pegs non-dominant hand	-3.037	.016
2	Material use	-4.643	.001
2	Visual-motor integration	-2.684	.025
2	Spatial perception	-4.665	.001
3	Material use	-3.428	.027
3	Spatial perception	-2.994	.040
5	Spatial perception	-5.196	.035
5	Pegs non-dominant hand	-8.000	.015

*Note.* Only significant results are presented in this table.

Right-handed children made significant progress in writing speed, material use, spatial perception, and peg test (dominant and non-dominant hand), whereas the left-handed children only made significant progress in material use. Data were corrected for age change over 12 weeks. Finally, statistical power on the sample size in the present study ( $N = 31$ ) was calculated as adequate (100%) at the recommended .08 level using the population mean from a study to determine the normative data for the SASP on an Australian Population (Wesson & Kispert, 2003).

### **Discussion**

This study sought to determine whether the ABSS could improve development of bilateral integration and spatial skills in primary school children beyond what could normally be expected to occur in a 12-week school term. It is theorized that improved spatial skills and bilateral integration would, over time, also result in reduced letter and number reversals in writing and in improved reading competency. The results reveal that following the children's use of the ABSS there were significant age-corrected improvements in their visual-spatial perceptual skills.

In particular, the results demonstrated significant improvements in the children's post ABSS understanding of spatial concepts, writing speed, spatial awareness of letter positioning on the lines, fine-motor speed (placing pegs), and material use. These outcomes are congruent with the results of earlier research in visual-spatial perception and its influence on academic

performance; however, these earlier studies were not based on the ABSS program (Decker et al., 2011; Humphreys et al., 2004; Massengill & Sundberg, 2006). If the spatial-perceptual skills required for reading literacy, geometry, and other mathematical computations improve, then one can extrapolate that the reading, geometry, and mathematical computations would also improve (Chan, 2010; Chinn, 2002; Decker et al., 2011). The research question: "Will regular use of the ABSS improve the development of bilateral integration and spatial skills in primary school children?" can thus be answered. The use of the ABSS on a regular basis did result in a positive improvement in the spatial skills of the children participating in the project. This was reflected in the occupation of handwriting and improved spacing of letters on the lines.

In relation to the assessment of the ABSS, the researchers tentatively postulated that the creativity applied within the confines of the program's spatial board is a factor that translated to the improved letter positioning on the lines. This assumption is consistent with previous research (not on the ABSS) that has similarly linked improved visual-perceptual skills to better writing skills (Case-Smith, 2002; Chan, 2010; Chinn, 2002; Decker et al., 2011). Additionally, the need to stack and balance ABSS shapes in a vertical plane for some constructions is considered to have facilitated improvements in the children's fine motor speed and accuracy. This assumption is consistent with research findings that demonstrate that improvements in perceptual and

bilateral integration occur when the motor component of a remediation task is integrated at the same time with a perceptual-spatial component (Ayres, 1973; Jordan, 1990). There is minimal clarity of the response to the research question: “Will the development of spatial skills and bilateral integration reduce the occurrence of letter and number reversals in writing and reading?” as the assessments used in this project were not sufficiently sensitive to determine the change of frequency of letter and number reversals. However, letter and number reversals may be reduced with the enhancement of spatial understanding as was seen in the improved spacing when writing.

Improvements in the children’s performance were not evidenced in the VMI, VP, and VM skills subscales. This, however, may be a facet of the project being conducted over a relatively short time period and the fact that access to the children was limited to the actual intervention session. This limited access may have had an impact on the results, as the VMI, VP, and VM assessments may not be sensitive to minor change over such a short time frame. Therefore, further evaluations of the ABSS now need to be conducted on children (and adults) in control and experimental groups over a longer period of time and with more frequent exposure in order to substantiate (or repudiate) the positive results found in this study (Benn, Venter, Aucamp, & Benn, 2000; Burtner et al., 2006; Murray-Slutsky & Paris, 2000).

Finally, postintervention anecdotal accounts provided to the administering therapists

by the children’s parents all concerned noticeable improvements in the sample. For example, the parents of one seven-year old child reported observed improvements in the child’s knife and fork control when eating, and that the child’s organizational skills had improved. Another mother of a 10-year old stated that she had noticed considerable improvement in the legibility of her daughter’s handwriting, while a third parent of a nine-year old boy commented that his motivation and confidence had improved considerably. In relation to school-based practice, therefore, the ABSS has a potential to aid in the development of underlying skills that affect the outcomes in handwriting, reading, letter and number reversal, and mathematical computations. Further research using specific academic assessments, such as a reading scale, will strengthen support for the use of the ABSS in the pediatric school system to enhance academic performance. Thus, the research question: “Will regular use of the ABSS improve spatial skill more than the normal classroom teaching processes to which all children are exposed?” can cautiously be answered positively. However, further research is required in a control group to determine whether this progress is statistically and clinically significant.

### **Limitations**

The range of students who volunteered to participate in the project, as well as the time that was available to the researchers to conduct the evaluation, limited the study’s scope. For instance, due to the extended time frame involved in administering the ABSS intervention to the children over two terms, three of the third term

group participants left the study prior to its completion. The resultant reduction in the size of this group from 10 children to seven made between statistical group comparisons problematic. Moreover, the study's results should also be interpreted with a degree of caution, as other simultaneous learning experiences undoubtedly occurred over the course of the school term. Thus, more research is required to conduct comparisons of the intervention with other interventions claiming to improve bilateral-spatial concepts and to research the effectiveness of the ABSS program among both the child and adult populations of individuals with visual-spatial and visual- motor perceptual difficulties.

### **Implications for Future Research**

The ABSS has the potential for further development and usefulness in providing intervention for those who have bilateral-visual perceptual difficulties. For the clinician, this

provides another tool for intervention, specifically with a population who have difficulty with bilateral integration and spatial perception, but who also have the motor coordination to stack the shapes. There are also components involving other perceptual skills and memory that can be researched. The continued research of this activity will add to the evidence base of effective intervention.

Future research should involve projects using a true experimental design to build the evidence of the effectiveness of this tool. In addition, research can apply the ABSS to an adult population in order to substantiate or repudiate the effectiveness of the ABSS in the intervention of adults who experience bilateral integration and spatial-skill deficits. Further, research comparing the ABSS to other interventions believed to have similar outcomes will also add to the evidence base of this intervention's effectiveness.

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