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השפעת למידה מתוקשבת בתקופת הקורונה על הפערים הלימודיים של ילדים עם קשיי למידה בחשבון

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לקויות למידה, בית ספר לחינוך על שם סימור פוקס האוניברסיטה העברית בירושלים

האוניברסיטה העברית בירושלים

תוכן עניינים

האוניברסיטה העברית בירושלים

תקציר

במהלך השנים האחרונות, מחקרים רבים בחנו את ההשפעות של הסגרים בתקופת הקורונה על לימוד מתמטיקה, וגילו כי הסגרים בעיקר יצרו קשיים ופערים בלימוד המתמטיקה. קיימים רק מחקרים מעטים בקונטקסט הישראלי אשר בדקו את ההשפעה של סגרים על לימוד המתמטיקה. זה חשוב בעיקר בקונטקסט הישראלי כיוון שעל פי דיווחי מנהלים המורים הישראלים בתקופת הסגרים לא היו מוכנים מספיק לשימוש בעזרים דיגיטליים (ראה תוצאות של מבחן הPISA). המחקר הנוכחי ניסה לבחון את ההשפעות ארוכות הטווח וקצרות הטווח של סגרי הקורונה על ילדים אשר היו בכיתה א' וב' בזמן סגרי הקורונה ובזמן הבדיקה שלהם היו בכיתה ג' או ד'. אוכלוסייה זאת היא מיוחדת כיוון ש 1) בגיל צעיר קשה לבצע למידה מרחוק לאורך זמן וללא עזרת הורים. 2) בכיתה א' וב' נלמדים היסודות של המתמטיקה. מטרה נוספת של המחקר הנוכחי היא לבחון כיצד סגרי הקורונה השפיעו על תלמידים עם לקויות למידה בחשבון.

בחלק הראשון נבדקה ההשפעה של סגרי הקורונה על יכולת שליפה של עובדות חשבוניות. עובדות חשבוניות הם תרגילים פשוטים (כדוגמת 2 + 4) תרגילים אשר מכיתה ג' אמורים להיזכר בעל פה ולא דורשים חישוב. נמצא כי עובדות חשבוניות הם יכולת 1) שדורשת אימון מפורש ו2) מנבאת יכולת פתרון תרגילים מורכבים יותר. בחלק הזה השווינו את הביצועים של ילדים לאחר הקורונה (2022-2023) לתוצאות ילדים לפני הקורונה (2018) מאותם בתי הספר ושהיו באותם הגילאים. נמצא כי בעובדות חיבור, שנלמדו בזמן סגרי הקורונה, ילדים לפני הקורונה היו טובים יותר מאשר ילדים לאחר הקורונה. אבל ביחס לעובדות כפל, שנלמדו לאחר סגרי הקורונה, ילדים אחרי הקורונה ללא קשיים הראו, באופן מפתיע, ביצועים טובים יותר מאלו לפני הקורונה. ילדים עם לקויות למידה בחשבון אחרי סגר הקורונה הראו ביצועים פחותים יותר בחיבור וכפל ביחס לילדים ללא קשיים חשבוניים עם הקשיים חמורים יותר בכפל.

ממצע זה (לגבי שיפור יכולת הכפל לאחר סגרי הקורונה לעומת לפני) היה מפתיע והנחנו כי הוא קשור לשיפור של מורים בשימוש בעזרים דיגיטאליים לאחר הקורונה. בשביל לבדוק היפותזה זאת, בחלק 2 של המחקר עשינו שאלון למורים אשר בוחן את ההבדלים בשימוש בעזרים דיגיטליים לפני ואחרי הקורונה. בשאלון הזה נמצא כי באופן כללי מורים משתמשים יותר בעזרים דיגיטליים אחרי הקורונה לעומת לפני הקורונה. עוד נמצא כי הפער בשימוש בעזרים דיגיטליים היה הרב ביותר היה בעבודה עצמית של ילדים במהלך הכיתה עם עזרים דיגיטליים ובשעורי הבית.

בחלק השלישי של העבודה הזאת רצינו לבחון האם הילדים שנתיים אחרי הקורונה, אשר חוו את סגרי הקורונה בכיתות א' וב', הצליחו להשלים את הפערים הללו ביחס לנושאים שנלמדו בזמן הסגרים. בשביל לבחון את זה יצרנו מבחן ממוחשב הבוחן את הנושאים הנדרשים בתוכנית הלימודים אשר נלמדו במהלך הסגרים. בגלל שהילדים שנבחנו הם שנתיים לאחר הקורונה הנחנו כי הם הצליחו להשלים את הפער ולהראות ביצועים בדיוק גבוה מאד. גם פה השווינו בין ילדים מתקשים לילדים שאינם מתקשים בחשבון.

התוצאות מראות כי הילדים שלמדו בכיתה א' ובכיתה ב' ללא קשיים הצליחו להשלים את הפער ומראים ביצועים כמעט מושלמים בכל התכנים הנלמדים בתוכנית הלימודים. פרט לקשים מאד קטנים בתחומים הערכה על ציר מספרים לילדים שעברו את הסגרים בכיתה א' ומבנה עשרוני וחיסור לילדים שלמדו בכיתה ב' בזמן הסגרים. אולם בילדים עם לקויות למידה, הפערים שלהם היו קשורים לכיתה בה למדו בזמן הסגרים. ילדים עם לקויות למידה אשר למדו בכיתה א' בזמן הסגרים הראו קשיים בנונים חמורים בתחומי סדרות, חיסור וזוגיות ואילו ילדים עם לקויות למידה אשר למדו בכיתה ב' בזמן הסגרים הראו קשיים חמורים מאד ברוב התחומים שנבדקו פרט להשוואת ספרות. ולכן נראה כי ילדים עם קשיים בכיתה ב' הם אלו שמראים את הקושי הרב ביותר בעקבות סגרי הקורונה. אנחנו מניחים כי הם התקשו בעיקר בלמידה של המבנה העשרוני בלמידה מרחוק ולמידה מסורתית במסגרת הכיתה של מבנה עשרוני עשוייה לסייע להם להשלים את הפערים שנוצרו.

לעבודה הנוכחית משמעות גדולה בהקשר הישראלי היום, בעיקר כי התלמידים הללו, אשר עברו את סגרי הקורונה בכיתה א' וב' חווים את מלחמת חרבות ברזל היום בכיתה ג' וד' אשר סביר להניח שהגדילה עוד את הפערים המוצגים במסמך זה.

המסקנות העיקריות של מסמך זה הם שהשפעת סגרי הקורונה של לימוד מתמטיקה בית ספרית הוא מאד מורכב ותלוי 1) בנושא הנלמד 2) בגיל הילדים בהם הם עברו את סגרי הקורונה 3) בקיום או אי קיום קשיי למידה בחשבון. בנוסף למדנו כי לסגרי הקורונה היו גם השפעות חיוביות במידת מה על מערכת החינוך הישראלית כיוון שהוא חייב את המורים להשתמש בעזרים דיגיטליים שלאחר מכן הוטמעו בכיתות ועזרו במעבר למאה העשרים ואחת מבחינת שיטות לימוד.

השפעת למידה מתוקשבת בתקופת הקורונה על הפערים הלימודיים של ילדים עם קשיי למידה בחשבון - דוח מסכם

למידה מתוקשבת - תמורות במערכת החינוך הישראלית

המאה ה-21 יצרה שינויים מרחיקי לכת בתפיסת הכיתה וסביבת הלמידה. בתהליך למידה מתוקשבת המורים והתלמידים לא חייבים להיפגש בסביבה פיזית, בהמצאות רשת האינטרנט ניתן לייצר כיתה וירטואלית שאינה כבולה לארבע קירות ולזמן קבוע (איתן, 2006). השינויים הטכנולוגיים המאפיינים את העידן הדיגיטלי, מציבים בפני מערכת החינוך אתגרים המחייבים התאמת תוכנות הלימוד ואסטרטגיות הוראה לטכנולוגיות חדשניות. תכנית התקשוב "התאמת מערכת החינוך למאה ה-21" החלה לפעול בישראל ב-2010, כאשר מטרת התוכנית היא יישום הוראה דיגיטלית מתקדמת בכלל בתי הספר בישראל, תוך הקניית מיומנויות מהמאה ה-21, בשילוב טכנולוגיות מידע ותקשורת (מגן-נגר ואחרים, 2014). למרות רפורמת התאמת מערכת החינוך למאה ה-21, פרה עידן הקורונה למידה מתוקשבת היוותה חלק מאד קטן ממערכת החינוך הפורמאליות (מגן-נגר ואחרים, 2014).

השפעת הקורונה ומעבר משיטות למידה מסורתית לשיטת למידה וירטואלית

התפרצות מגפת הקורונה הביאה באחת לסגירה של כל מוסדות החינוך. עידן הקורונה והסגרים הארוכים שחווינו חייבו מגוון גורמים חינוכיים לזנוח ברגע אחד שיטות לימוד מסורתיות ולעבור ללמידה וירטואלית. המעבר ללמידה וירטואלית היה אמור ליצור שינוי אדיר במערכת החינוך, מאחר והוראה בסביבה כזו מאפשרת התאמה למגוון של סגנונות הוראה. שילוב טכנולוגיה בהוראה יכולה לזמן שינוי פרדיגמטי בשיטת הלימודים, הכולל שיטות ממוקדות תלמיד, שיעודד את הלומדים להתנסות בתהליכי חקר (איתן, 2006), בנוסף למרחב למידה גמיש, הכולל גישה לחומרי למידה מגוונים, ללא הגבלת זמן ומקום (Korhonen et al., 2019; Serianni & Coy, 2014), בניגוד לציפיות אלו, מערכת החינוך חוותה קשיים רבים ביחס להסתגלות ללמידה וירטואלית. מורים השתמשו בשיטות מסורתיות בלבד ללא שינוי פרדיגמטי וחוו בעיות טכניות בשימוש בעזרים דיגיטליים. מצד התלמידים, בניגוד לכיתת הלימוד המסורתית, שמספקת הזדמנויות שוות לכל הלומדים בה, הפערים בין התלמידים בכיתות הווירטואליות עצומים. תלמידים ממשפחות בעלי אמצעים מקבלים סביבה שקטה ללמידה (חדר פרטי) ללא הפרעות, מחשב אישי ולפעמים שעורים פרטיים. תלמידים ממשפחות בעלות אמצעים פחותים, פעמים רבות, לומדים בסביבה פחות מותאמת, העשויה לכלול הפרעות ורעשים מצד האחים, הצורך לחלוק את המחשב או אפילו להשתמש בטלפון נייד בזמן הלמידה. בנוסף לכך, מחקרי עבר העידו כי ללמידה מרחוק יש גם היבטים מוטיבציוניים וחברתיים שליליים (Lamanauskas & Makarskaite-Petkeviciene, 2021).

מצב זה אפילו מחריף בקרב ילדים עם לקויות למידה וממשפחות בעלות אמצעים מעטים. אולם, הלמידה הווירטואלית יכלה ליצור גם מגוון הזדמנויות לתלמידים עם לקויות למידה: אפשרות לשאול את המורה שאלות באופן ישיר, למידה בקבוצות קטנות וצפיה חוזרת בהקלטות השיעור (Serianni & Coy, 2014).

במטרה לבחון את ההשפעה של המעבר ללמידה וירטואלית על תלמידים עם לקויות למידה, נתמקד בתלמידים המאובחנים עם קשיים חמורים במתמטיקה.

<u>השפעת למידה מתוקשבת בתקופת הקורונה על לימוד המתמטיקה בעולם ועל נבדקים עם לקויות למידה</u>

טרם מגפת הקורונה, מחקרים הצביעו על מספר יתרונות בלמידה מקוונת עבור תלמידים עם לקויות למידה : לדוגמא גישה חופשית ומאפשרת חזרה של חומר הלימוד (Serianni & Coy, 2014) ועליה במודעות הורית לגבי הנלמד (Sorensen, 2019).

בהקשר ללמידה של מתמטיקה בסביבה וירטואלית, בפרט עבור תלמידים עם לקויות למידה, נמצא כי היבטים אלה מסייעים להוראה מיטבית 1) לימוד ספיראלי 2) חזרתיות 3) שימוש בדוגמאות (Kadarisma & Juandi, 2021) .

אולם, לא ניתן להסיק באופן ישיר מהמחקר התיאורטי על אופן הלמידה מרחוק ויישומה הלכה למעשה בתקופת הקורונה, אך ניתן להבין כי תקופה זו היתה מאתגרת מבחינת המורים וההורים. למידה און ליין של ילדים עם לקויות למידה דורשת מעורבות הורית גדולה (Burdette & Greer, 2014) שלעתים קרובות מהווה אתגר עבור ההורים. הקושי העיקרי מבחינת הילדים הוא אובדן רשת התמיכה של בית הספר (Lee, 2020), שהיא בעלת חשיבות עליונה לתלמידים עם לקויות למידה. בנוסף, העובדה שהורים רבים לא מצליחים לסייע לתלמידים הללו מבחינה לימודית, מקשה מאד על ילדים עם לקויות למידה, אשר מתקשים להבין ולהתמיד בלמידה מרחוק (Schuck & Lambert, 2020) וזקוקים להוראה ישירה ומתאמת (Baroody, 2006). אפילו בקרב הורים לתלמידים ללא לקיות למידה נמצא כי 10% מההורים הנבדקים הראו מוטיבציה נמוכה לעזור לילדהם עם מטלות הלמידה און ליין (Garbe, Ogurlu, Logan, & Cook, 2020).

אתגר נוסף בלמידה מקוונת הוא שהמורים אינם מצליחים לזהות את מקור הקושי של התלמיד ולהתאים עבורו פעילות מותאמת בזמן השיעור. תלמידים החווים קשיים אובייקטיביים מרגישים לעתים קרובות מתוסכלים מהמשימות, אינם מבינים את הנדרש באופן מלא ואז עובדים שרירותית ובצורה לא מקדמת (Wen et al., 2020).

במטרה להבין את מורכבות הלמידה מרחוק עבור תלמידים מתקשים במתמטיקה, נתמקד תחילה באפיון תלמידים אלה ונבין את האתגר העומד בהבנת מקור הקושי הראשוני של הלקות.

<u>הטרוגניות הקשיים בחשבון ותתי סוגים</u>

דיסקלקוליה התפתחותית (Developmental Dyscalculia - DD) או קשיים חמורים בחשבון (Mathematical difficulties MD) הן הפרעות למידה המתחילות מגיל צעיר ומתאפיינות בקשיים במגוון יכולות חשבוניות. תחום היכולת המתמטית מאופיין בהטרוגניות רחבה ובשל כך דורש מיומנויות קוגניטיביות מגוונות (Dowker, 2005). היכולת המתמטית מושפעת הן מיכולות ספציפיות למתמטיקה (Dehaene, 1992; Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999; Geary, Hamson, & Hoard, 2000) והן מיכולות כלליות, בעלות השלכה על הביצועים המתמטיים (Ashkenazi, Golan, & Silverman, 2014; Ashkenazi & Henik, 2010; Silverman & Ashkenazi, 2022). לקות למידה במתמטיקה משפיעה על 3%-6% מהאוכלוסייה (Shalev & Gross-Tsur, 2001) ובאה לידי ביטוי בקשיים בביצוע של מיומנויות בסיסיות, כגון שליטה בעובדות היסוד (Geary, 2004).

מגוון תיאוריות שונות התייחס למקור הקשיים בחשבון. משנות ה-90 קיימת הסכמה רחבה לכך כי היכולת להבין כמות מוערכת ולהשוות בין כמויות היא מולדת ומבוססת על מנגונונים מוחיים ספציפיים. תיאוריות הקשיים בכמות טוענות כי הבדלים אינדיבידואלים ביכולות המולדות להבחנת כמות משפיעים באופן ישיר על יכולות מתמטיות בוגרות ובית ספריות (Halberda & Feigenson, 2008; Halberda, Mazzocco, & Feigenson, 2008). ולכן, תיאוריות אלה יניחו כי הקשיים הבסיסים של נבדקים עם דיסקלקוליה התפתחותית יתרכזו בעיבוד נומרי בסיסי, הכולל השוואה בין כמויות סימבוליות ולא סמבוליות. על פי תיאוריות הקושי בעיבוד כמות, כמות סימבולית, שנלמדת בצורה מפורשת בבית הספר ומערכת הספרות המערביות היא נגזרת ישירה של הבנת הכמות המולדת. אולם, תיאוריות משנים מאוחרות יותר גורסות כי להבנת כמות בדידה תפקיד קטן ביכולות אריטמתיקה בוגרות. לדוגמא, ב 2013 בחנו Szucs, Devine, Soltesz, Nobes, & Gabriel,מה הם הקשיים העיקריים של ילדים עם דיסקלקוליה בבריטניה. הם בחנו שתי תיאוריות אלטנרטיביות. 1) נבדקים עם דיקסלקוליה התפתחותית העתידיים להראות קשיים בהבנת כמות 2) נבדקים עם דיקסלקוליה התפתחותית העתידים להראות קשיים כלליים. התוצאות הראו כי נבדקים עם קשיים בחשבון תיעדו קשיים ביכולות זיכרון עבודה ויזואלי מרחבי ויכולות אינהיבציה, ללא כל קושי בעיבוד כמות. מאז, קיימות מספר השגות לגבי התיאוריה של הקושי בעיבוד כמות כבסיס לדיסקוקליה. ראשית, נטען כי התיאוריה הקושי בהבנת כמות לא מתייחסת באופן נפרד להתפתחות של המערכת הסימבולית המדוייקת של עיבוד כמות שהיא שונה מאד מזאת המוערכת המולדת (Noel & Rousselle, 2011). על פי Noel and Rousselle, (2011) הקושי העיקרי של ילדים עם קשיים חמורים בחשבון הוא בהתפתחות של המערכת הסימבולית של עיבוד כמות, אשר איננה קשורה במשורין להתפתחות המערכת הלא סימבולית. כפועל יוצא מכך, נבדקים צעירים יראו רק קושי בהשוואה סימבולית, אך לא בהשוואה לא סימבולית.

שנית, מקורות רבים שאינם חשבוניים מעורבים בביצוע מטלות בתחום החשבוני, ולכן, תיאוריות אחרות גורסות כי לנבדקים עם דיסלקוליה התפתחותית יש קשיים ביכולות כלליות הנקשרות לתחום זה, כדוגמת זיכרון עבודה, זיכרון כללי, קשב או יכולות מילוליות (Szucs, Devine, Soltesz, Nobes, & Gabriel, 2013). לדוגמא, במטא אנליסיס שהתבצעה ב2016 נמצא כי יש שני סוגים של קשיים בחשבון, קשיים טהורים המלווים בחולשה של זיכרון העבודה המרחבי וקשיים שנמצאים בקומורבדיות עם קשיי קריאה שמלווים בקושי בזיכרון עבודה מילולי (Szűcs, 2016).

שלישית, נטען כי יש להסתכל על הרצף ההתפתחותי של חשבון, אשר תיאוריית עיבוד כמות התעלמה ממנו. על פי תאוריה זאת, יש תתי סוגים של דיסקלקוליה התפתחותית, על פי השלב ההתפתחותי בו החלו הקשיים. תת סוג אחד הוא דיסקלקוליה טהורה, אשר מקורה הוא בקושי מולד לתפיסת כמות לא סימבולית ותת סוג שני, שהוא דיסלקולוליה קומורבידית, שתופיע בעיקר עם קשיי קריאה וקשב, ותשפיע על ההתפתחות המאוחרת יותר של המערכת הסימבולית (Von Aster & Shalev, 2007).

מאז יש מחקרים רבים הגורסים כי הקושי בחשבון איננו אחיד וקיימים מגוון פרופיליים של קשיים בחשבון. לדוגמא, מחקרים אחרונים גורסים כי קיימים מספר רב של תתי סוגים של דיסלקלקוליה. לדוגמא, Skagerlund and Träff (2016) מצאו כי יש שני תתי סוגים של הלקות - האחד המבוסס על קושי בעיבוד כמות מוערכת ולא סימבולית, כפי שתיאוריות הבנת הכמות תיארו (Halberda & Feigenson, 2008; Halberda et al., 2008) ואחר עם קושי סימבולי בלבד (Noel & Rousselle, 2011).

מחקר אחר מצא 5 תתי סוגים של דיסלקוקליה ובדק את היציבות שלהם לאורך זמן (Chan & Wong, 2020). בדומה למחקר הקודם, נמצאו שני תתי סוגים של דיסקלקוליה שקשורה לקושי לא סימבולי וקושי בקידוד סימבולי ונמצאה קבוצה נוספת בעלת קושי בזיכרון עבודה, שהתגלתה רק בכיתה ב' ולבסוף קבוצה בעלת קושי מינימאלי בחשבון (Chan & Wong, 2020). לעומת זאת, במחקר אחר לא הצליחו כלל למצוא תתי פורפולים של תתי סוגים של קשיים והסיקו שחשבון הוא נושא הטרוגני מידי בשביל להבחין בין תתי סוגים (Huijsmans, Kleemans, van der Ven, & Kroesbergen, 2020).

יום יש הסכמה יותר רחבה בספרות לגבי קיום של תתי סוגים של קשיים בחשבון, אבל עדיין מספר שאלות נשארו פתוחות ביחס לקשיים בחשבון.

1) מה היא האטיולוגיה לקשיים בחשבון. 2) מה הם תתי סוגים של קשיים בחשבון ו3) מה המקום של ארועי חיים שגרמו לפער לימודי ביצירת קשיים בחשבון.

מגוון צוותים חינוכיים מעידים כי עידן הקורונה יצר פערים לימודיים בקרב תלמידים רבים, ביחוד בקרב תלמידים עם פוטנציאל ללקות למידה בחשבון.

הפער נובע, לדעתנו, בשל תרגול ולמידה לא עקביים בשלבי הביסוס הראשוניים (כיתות א'-ב'), המהווים אבני בניין למתמטיקה בוגרת יותר (Geary, 2004) ובקרב תלמידים מתקשים פער זה מועצם על רקע של קשיים חשבוניים ספציפיים.

במטרה להבין את עומק הקשיים שנוצרו בעקבות למידה מקוונת בכיתות היסוד בקרב תלמידים ללא קשיים ראשוניים בחשבון ובקרב תלמידים מתקשים, נערך מחקר זה.

בנוסף לכך, מיפוי הקשיים במחקר הנוכחי, יכול בעתיד לאפשר יצירה של תוכניות התערבות ספציפיות לשיפור המיומנויות החשבוניות לצמצום הפערים הלימודיים שנוצרו בתקופת הקורונה.

עד היום לא פורסמו מחקרים רבים שבוחנים את ההשפעה של המעבר המהיר בזמן מגפת הקורונה מלמידה מסורתית בכיתה ללמידה מתוקשבת בישראל. במיוחד, לא נבחנו האפקטים הללו על תלמידים עם לקויות למידה ועל תלמידים מרקעים מוחלשים. מחקרים על למידה מתוקשבת באופן כללי מראים תוצאות מעורבות. אולם, בזמן הקורונה כאמור, המעבר היה מהיר ופתאומי, ללא הכנה של המורים והלומדים.

<u>המחקר הנוכחי</u>

למחקר הנוכחי נבחרה קבוצת תלמידים עם קשיים בחשבון בכיתות ג' וד' וקבוצת נבדקי ביקורת מתואמי גיל, מין וכיתת לימוד. **המטרה הראשונה** של המחקר הנוכחי היא בחינה של השפעת המעבר ללמידה וירטואלית על תלמידים עם וללא לקויות למידה, בעזרת מגוון שאלונים להורים. **מטרה נוספת** היא בחינה של ביצועים חשבוניים של ילדים שלמדו בתקופת הקורונה בכיתות א' וב'. אנו ננסה לאפיין כיצד השפיעה הלמידה המתוקשבת במהלך הסגרים על תלמידים בעלי לקויות למידה וללא לקויות למידה. אנחנו מאמינות כי תקופת הלמידה הווירטואלית בזמן הסגרים הגדילה את הפערים בין תלמידים מתקשים ללא מתקשים, וכי הלמידה המתוקשבת לא הטיבה עם התלמידים בעלי קשיים בחשבון, אשר לפי הספרות המחקרית זקוקים להוראה ישירה, מדורגת, עקבית וחווייתית (Baroody, 2006).

בשלב הראשון, ערכנו מבדקים בתחום היכולות הספציפיות והכלליות במתמטיקה, בכדי לעמוד על החוזקות והקשיים של תלמידי המחקר. במקביל, הורי התלמידים נתבקשו למלא שאלון בדבר הלמידה של הילדים בתקופת הקורונה.

מבחנים אשר בחנו יכולות ספציפיות במתמטיקה כללו את סוללת המבדקים הבאה:

השוואה לא סימבולית - במשימה זו הילדים נתבקשו להשוות בין צברי נקודות. השוואה לא סימבולית מייצגת יכולת מולדת לייצוג כמות מוערכת ונמצאה קשורה באופן הדוק ליכולת חשבונית במהלך בית הספר. קיימות אי הסכמות בספרות לגבי קושי של נבדקים עם דיסקלקוליה במטלה זאת. אולם, מחקר מטה אנליסיס שבדק מגוון מחקרים מדווח שהקושי של דיסקלקולים התפתחותיים בהשוואה לא סימבולית תלוי בגילם. בעוד שבגיל צעיר נראה

יכולת תקינה של השוואה לא סימבולית עם קשיים בהשוואה סימבולית, בגיל מבוגר יותר מכיתה ג' ואילך, נראה קושי בהשוואה לא סימבולית וגם סימבולית בילדים עם דיסקלקוליה (De Smedt, Noël, Gilmore, & Ansari, 2013). לכן, אנחנו מצפים לקשיים בהשוואה לא סימבולית בילדים עם דיסקלקוליה במחקר הנוכחי.

שנית, נבחנה **יכולת השוואה סימבולית** של נבדקים: במהלך הניסוי הזה נבדקים נחשפו לשני מספרים חד ספרתיים ונתקשו להחליט אילו מבין המספרים גדול יותר. זמן התגובה למשימה זו והדיוק משתפרים עם הגיל. בנוסף, ניתן לראות במשימה את אפקט המרחק – זמן התגובה יורד והדיוק עולה ככול שהמספרים המושווים יותר רחוקים נומרית (לדוגמא 3 ו7), לעומת המצב שהם קרובים נומרית (Ashkenazi, 2023). ניתן לראות כי נבדקים עם דיסקלקוליה התפתחותית מראים קשיים במשימה זו, ביחס לנבדקים ללא קשיים בזמן התגובה ובדיוק וכן באפקט המרחק (De Smedt et al., 2013).

שלישית **נבדק שטף חשבוני**. באמצעות מבחן נייר ועיפרון הלמידים נתבקשו לפתור כמה שיותר תרגילי חיבור בדקה וכפל בדקה. נבדק קצב הפתרון של עובדות חשבוניות בסיסיות. מצאנו את התחום הזה חשוב במיוחד, מאחר והוא מאפשר להסיק על אסטרטגיות יעילות/לא יעילות לפתרון וכמו כן, לאור התוצאות הקיימות של מבחן זה משנה 2008 (טרם הקורונה), מתאפשרת ההשוואה של ביצועי תלמידים תקינים בין שתי התקופות. ראה נספח 1 לדוגמאות של המטלה.

רביעית **נבדק ייצוג על ציר המספרים.** המספרים אמורים להיות מיוצגים מרחבית על ציר מספרים מנטאלי, ולכן האסוציאציה בין מספר לבין מרחב היא חשובה בהבנת הקשיים בחשבון. מגוון מחקרים מראים קשיים בקישור בין המרחב לבין מספר בנבדקים עם דיסקלקוליה התפתחותית (Ashkenazi & Henik, 2010).

- ידוע כי יכולות חישוב תלויות במגוון יכולות כלליות, כגון יכולות ניהוליות, יכולות שפה, יכולות זיכרון עבודה ועוד. לכן, מקבץ המבחנים השני בחן יכולות קוגניטיביות כלליות.

ראשית נבחנו **יכולות אינהיביציה** בעזרת משימת הפלנקר (Ashkenazi & Blum-Cahana, 2023). ידוע כי יכולות אינהיביציה הן קריטיות ליכולות חשבוניות (Ashkenazi & Blum-Cahana, 2023) ומשימה מצוינת לבדיקת אינהיביציה היא הפלנקר, בה מוצגים על המסך סדרת דגים הפונים שמאלה או ימינה. על הנבדק להתעלם מהדגים הפריפריאליים ולשפוט האם הדג האמצעי פונה שמאלה או ימינה.

שנית, נבחנה **יכולות קידוד**. על בסיס מבחן אינטליגנציה המחקר הנוכחי פיתח ניסוי ממוחשב שבו מוצג מקרא המקשר מספר וסימבול חדש ולא מוכר. בכל צעד הנבדקים נדרשים להגיד האם הסימבול תואם לערך המספר או לא. נמצא כי מהירות עיבוד היא מנבא משמעותי ליכולת חשבון ולקשיים בחשבון בשלל גילאים (Ashkenazi & Blum-Cahana, 2023; Peterson et al., 2016).

שלישית, נבחנה **יכולת שיום** מהיר של עצמים וספרות. שיום מהיר היא גם יכולת המשותפת לקריאה וחשבון ומקושרת לקושי קומורבידי בין שניהם (Peterson et al., 2016).
בנוסף, נבנה ניסוי הבוחן הבנה ושליטה בתכנים הנדרשים על פי תכנית הלימודים בכיתות א' וב', במטרה להבין כיצד הקורונה השפיעה על רכישת היסודות של חשבון בתקופה קריטית זו (Ashkenazi, Mark-Zigdon, & Henik, 2013).

נבדקים

סיווג הקבוצות למתקשים ולא מתקשים

קבוצת המתקשים בחשבון (MD)

בשלב הראשון ביקשנו ממורי בית הספר היסודי מכיתות רגילות במחוז הצפון לבחור קבוצת ילדים מכיתות ג' או ד' לפי:
1) דיווח המורה שהם סובלים מקשיים חמורים במתמטיקה.
2) לפי הישגים במבחנים מבוססי תכנית לימודים מתמטית בישראל (ציון עד אחוזון 20%).
המבחן המבוסס על תכנית לימודים מתמטית נערך לכל ילדי ישראל בשנים אלו.
ילדים שעמדו בשני הקריטריונים הללו הוגדרו כבעלי קשיים מתמטיים (MD).
ביקשנו גם מאותם מורים בבית ספר יסודי לספק לנו קבוצה נוספת של ילדים עם ביצועים ממוצעים או מעל הממוצע במתמטיקה. קבוצה זו הוגדרה כקבוצה ללא קשיים.
מאתיים ותשעה ילדים נבחרו מכיתות ג'-ד', מ-7 בתי ספר במחוז הצפון בישראל. 94 מהם היו מכיתה ג', 34 היו בנים (גיל ממוצע = 8.64, S.D. =0.53). ו-115 מכיתה ד', 47 היו בנים (גיל ממוצע = 9.83, S.D. =0.51).
מכיתה ג', 40 היו ללא קשיים ו- 54 היו MD, מכיתה ד' 48 היו ללא קשיים ו-67 היו קשיים קשים בידע מתמטי לפי מוריהם.
הורי כל המשתתפים חתמו על טופס הסכמה להשתתפות בניסוי. שניים ממשתתפי קבוצת ה-MD לא השלימו את כל הבדיקות והוצאו מהכלל. אחד המשתתפים בקבוצת MD עזב במהלך הניסוי עקב קשיים.

סיווג נבדקים לקבוצת הדיסקלקוליה ההתפתחותית

בשלב השני כל אחד מהמשתתפים שהוגדרו כ-MD, ביצע 4 תתי-מבחנים ממבחן האבחון KeyMath III, כולל ספירה, אומדן, חיבור וחיסור חישוב בכתב, כפל חישוב בכתב וחילוק. חישבנו את הציון הממוצע המתוקנן לפי גיל של מתמטיקה על פי מדריך המבחן, כדי לסווג את המשתתפים לקבוצות. כל משתתף עם ציון סטנדרטי של פחות מ-1.2- SD השווה ל-12% הנמוכים ביותר מהביצועים והוכנס לקבוצת דיסקלקוליה התפתחותית (DD). לאחר מכן בחרנו תת-קבוצה מהילדים ללא הקשיים שתשמש כקבוצת הביקורת לניתוח הנוכחי. מצאנו תת-

קבוצה של 23 ילדים שעמדו בקריטריונים של DD מכיתה ג' ו-23 ילדים ללא קשיים (מאותו כיתה ומין), מכיתה ג' ו-25 מכיתה ד' ו-25 ילדים ללא קשיים מתואמים (מאותו כיתה ומין).

<u>תוצאות ראשוניות</u>

<u>שאלון בדבר השפעות הקורונה חישוב אלפא של קרונבך-</u>

ראשית חישבנו אלפא של קרונבך. לבדיקת מהימנות הפנימית של השאלון. התוצאה היתה יחסית נמוכה (0.38). בשביל להגדיל אותה הורדנו 9 שאלות לקבלת הערך המתקבל על הדעת 0.82. כל הארבע שאלות שהראו הבדלים מובהקים בין הקבוצות נשארו בתוך השאלון.

<u>שאלון הורים בדבר השפעות הקורונה ניתוח גורמים אקפלורטיבי-</u>

בניתוח גורמים על 6 הפריטים בעלי המהימנות הגבוהה בשאלון מצא גורם 1 המסביר 52.61% מהשונות.

<u>טבלה 1 ניתוח גורמים אקספלורטורי</u>

	Factor 1 loading (52.61%)
Q3	80.
Q8	80.
Q5	73.
Q6	72.
Q14	67.
Q1	66.-

בהמשך ניסינו להשוות בין הקבוצות.

על השאלון ענו 50 הורים לילדים לא מתקשים, לעומת 33 הורים לילדים מתקשים.

נמצאו מספר הבדלים בין הקבוצות

1. הורים לתלמידים מתקשים ציינו שילדיהם הצליחו פחות לעקוב אחר הנעשה בשיעור.
2. הורים לתלמידים מתקשים ציינו שהיה לתלמידים קשה יותר לשמור על קשב במהלך השיעור.
3. הורים לתלמידים עם לקויות למידה ציינו כי לילדיהם היה קשה להסתדר במשימות המקוונות ללא עזרה. ההבדל בשאלה זאת היה הכי משמעותי.
4. ההורים לתלמידים עם ליקויי למידה מציינים כי תקופת הקורונה גרמה לפערים משמעותיים יותר מאשר בקרב ילדים ללא לקויות למידה.

התוצאות מוצגות בטבלה 2:

<u>טבלה 2-</u> השאלות בשאלון הקורונה עם התוצאה הממוצעת של כל אחת מהקבוצות וכן רמת מובהקות ההבדלים בין הקבוצות. שאלות המסומנות בכתב מודגש מובהקות לאחר תיקון בנפרוני להשוואות מרובות.

	The translated question	TD (n=50)		MD (n= 33)		
		Mean	*SD*	*Mean*	*SD*	*p*
1	**The student was able to keep track of what was going on during class**	**3.58**	**.01**	**3.09**	**.10**	**04***
2	The student was able to understand the teacher	3.50	.05	3.24	.87	25
3	It was harder for the student to study in a virtual compared to a frontal class	3.26	.43	3.85	.28	06
4	Digit learning aids, including short movies, helped the student understand the subject matter	3.65	.11	3.38	.98	25
5	**It was hard for the student to concentrate during virtual math class**	**3.06**	**.25**	**3.82**	**.13**	**006****
6	It was hard for the student to find symbols on the keyboard	2.51	.21	3.06	.43	07
7	The student performed the tasks that were given to him/her on time	3.88	.24	3.42	.09	09
8	**The student had a hard time performing the online task by himself and without help from others**	**2.95**	**.26**	**4.00**	**.06**	**001****
9	The student always had a quiet and isolated environment during online learning	3.38	.26	3.27	.35	71
10	The student always had the computer available for learning	4.04	.21	4.15	.18	68
11	The student left the online lesson only when it ended	4.33	.77	4.15	.23	43
12	The student used a mobile phone instead of the computer during learning	2.16	.96	1.94	.34	47
13	The student had a stable connection to the interment during online classes	3.90	.97	3.94	.20	87
14	**The Corona period resulted in significant learning gaps for the student**	**3.51**	**.34**	**4.15**	**.03**	**02***

* p< .05, ** p<.01 *** p < .001, bold font represents significance after Bonferoni

לתוצאות המלאות ראה נספח 1.

<u>תוצאות בדבר שטף חשבוני</u>

התלמידים נתבקשו לפתור כמה שיותר תרגילים באופן נכון בשתי דקות. ניתן להם דף עם עובדות חשבוניות בחיבור ודף נוסף עם תרגילי כפל, לכל אחד מהדפים ניתנה דקה.

המשתנה התלוי הוא מספר התשובות שהילד ענה נכונה בכפל וחיבור יחד.

בשנת 2008 הרצנו את המבדק הנוכחי ל-400 תלמידים מכיתות ג' וד' והוצאנו נורמות גיל.

במחקר הנוכחי הורצו 40 תלמידים מכיתה ג' ללא קשיים ו48 תלמידים מכיתה ד' ללא קשיים. על מנת לשמור על קבוצות בגודל קבוע נבחרה באופן רנדומאלי אותה כמות של תלמידים שהורצו ב2008.

נערכה אנובה בין נבדקית דו גורמית עם זמן (לפני/ אחרי) הקורונה וכיתה (ג' או ד') וסוג התרגיל אופרנט (חיבור או כפל).

אלו הם התוצאות

נמצא אפקט עיקרי לכיתה

$F(1,474) = 24.39$, partial $\eta^2 = .05$, $p = .001$.

ילדים בכיתה ד' פתרו נכונה יותר תרגילים מאשר ילדים בכיתה ג'.

נמצאה אינטראקציה בין סוג התרגיל לבין זמן.

$F(1,172) = 407$, partial $\mu^2 = .46$, $p = .001$.

נמצא כי בחיבור הקבוצה לפני הקורונה ($M = 19.7$, $SD = 7.56$) היתה יותר מדויקת מהקבוצה לאחר הקורונה ($M = 12.67$, $SD = 5.17$)

$t(181) = 10.52$, $p = .001$.

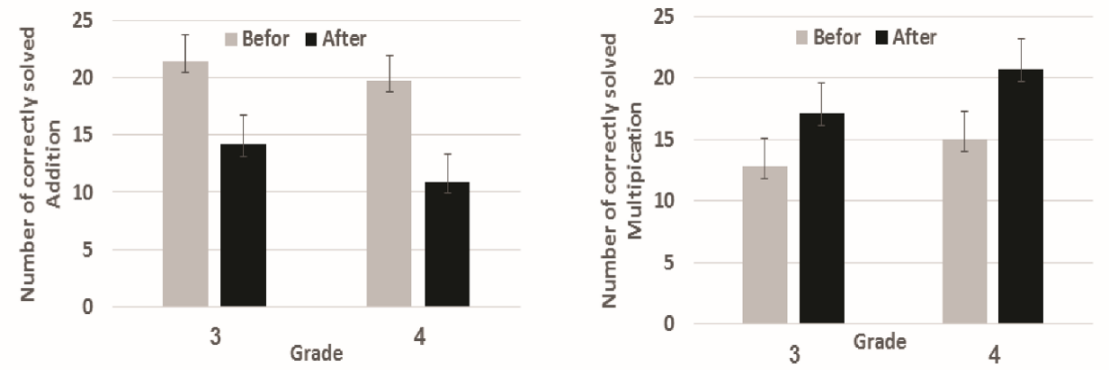
אולם הדפוס ההפוך נמצא לכפל

הקבוצה אחרי הקורונה ($M = 19.1$, $SD = 5.85$) היתה יותר מדויקת מלפני הקורונה ($M = 13.3$, $SD = 5.86$)

$t(476) = -8.37$, $p = .001$.

<u>ראה גרף 1 לתוצאות המדויקות</u>

גרף 1.



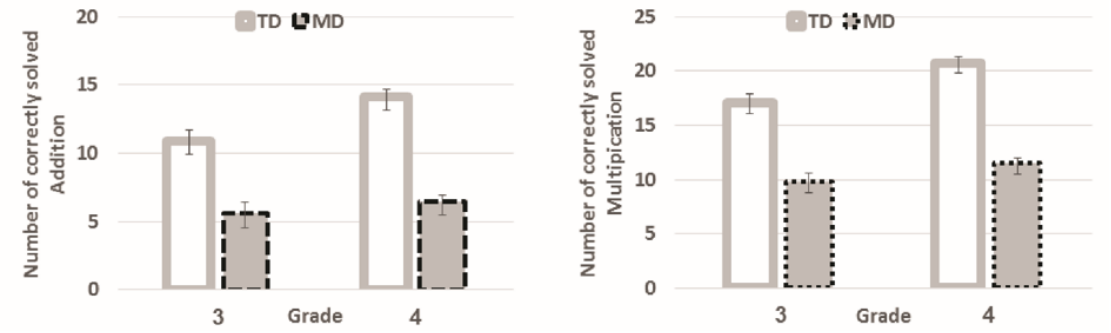
<u>מספר הבעיות שנפתרו בצורה נכונה במשימות שטף במתמטיקה כפונקציה של רמת כיתה וזמן (לפני או אחרי סגר הקורונה).</u>

בתוצאות חיבור נמצא כי הקבוצה שלפני נגיף הקורונה הייתה מדויקת יותר בהשוואה לקבוצה שאחרי. עם זאת, נמצאה מגמה הפוכה לכפל, שם נמצא שהקבוצה שלאחר הקורונה הייתה מדויקת יותר בהשוואה לקבוצה שלפני הקורונה.

בקרב ילדים מתקשים לעומת ילדים לא מתקשים בכפל וחיבור נמצא כי בקרב ילדים מתקשים יש פערים גם בכפל וגם בחיבור עם פערים גדולים יותר בכפל.

ראה גרף 2

גרף 2



גרף 2. מספר הבעיות שנפתרו בצורה נכונה במשימת שטף במתמטיקה כפונקציה של רמת כיתה וקבוצה (TD, MD, DD): כל המשתתפים בניתוח הנוכחי היו בכיתות א' ו-ב' במהלך סגר הקורונה. נמצא שגם עבור חיבור וגם כפל, ילדי TD פתרו יותר בעיות בצורה נכונה מילדי MD או הDD. עם זאת, ההבדל היה גדול יותר עבור כפל מאשר עבור חיבור.

<u>מסקנות</u>

ילדים ללא קשים לאחר הקורונה מראים קשיים בחיבור, אשר נלמד במהלך הקורונה. אולם לא מראים קשיים בכפל שנלמד ותורגל לאחר הקורונה. אנחנו מניחים שהשליטה בכפל היא כתוצאה מכך שהנושא נלמד לאחר הקורונה ושהצוות החינוכי השתמש הרבה יותר בעזרים דיגיטאליים בזמן תרגולו, אשר לא השתמשו בהם לפני הקורונה.

ילדים מתקשים מראים פערים גם בכפל וגם בחיבור עם פערים גדולים יותר בכפל.

ראה נספח 2

<u>תוצאות בדבר יסודות שהיו אמורים להילמד במהלך הקורונה.</u>

<u>תוצאות בדבר תלמידים שלמדו מרחוק בכיתה א'</u>

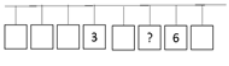
אנחנו בדקנו ביצועים של תלמידים במטלות מבוססות על תוכנית הלימודים של כיתה ג'.

בקבוצת הבקרה היו 43 ילדים, ובקבוצת המתקשים 31 .

בכל התחומים היו 3 חזרות, פרט להשוואות, בהן היו 4 חזרות. טבלה 3 מייצגת את התחומים שנבדקו על פי גיל .

<u>טבלה 3</u>- דוגמא לפריטים מתוך המבחן הממוחשב לבדיקה של תוכנית לימודים בכיתה א' ובכיתה ב' על פי נושא בתוכנית הלימודים ורמת הכיתה.

	1st	*2nd*
Closer to number	Who is closer to 7? 5 or 3	_____
Between numbers	What's number is between 8 and 15? 6, 9, 16,4	_____
Count up	Count from 11 to 21	_____
Enumeration		_____
Changing unit decade	_____	One changed the decade in 52 to 4 how much the number grow.
Create the biggest number	_____	Please create the biggest number from 6 and 3
Create the smallest number	_____	Please create the smallest number from 2 and 0
Estimation	_____	Whether the results of 54 +36 is larger or smaller than 100?
Find a number	_____	Find a number that is greater in 2 from 24
Equations	_____	3 + ? = 26
Multiplication	_____	3 X 6
Multiplication rules	_____	3 X 1
Read number	_____	Read the number 71
Comparison	Select the larger number 7 or 4	Select the larger number 13 or 29

	1st	*2nd*
Number line exact		
Number line estimation		
Parity	Select the even number 1, 9, 8, 5	Create all the even numbers from 4 and 2
Serious	__, 4, 6, 8	20, 40, 60, ___
Subtraction	18 - 7	98 - 76
Addition	4 + 3	43 + 38

<u>אלו הן התוצאות לילדים בכיתה ג'</u>

נמצא אפקט עיקרי לסוג התרגילים

$F(1,72) = 25.52$, partial $\mu^2 = .26$, $p = .0001$.

נמצאה אינטראקציה בין סוג וקבוצה

$F(1,72) = 17.96$, partial $\mu^2 = .20$, $p = .0001$

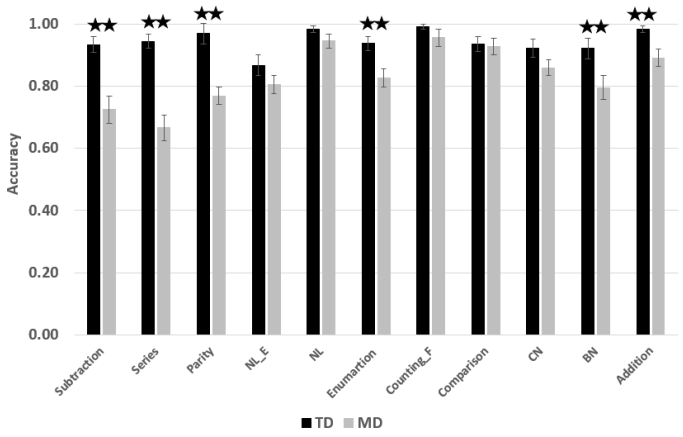
בשביל לפרק את האינטרקציה בין קבוצה לבין סוג התרגיל בדקנו

א. הבדלים בין קבוצות בכל אחד מסוגי התרגילים במבחן t

וכן בדקנו האם הביצועים של קבוצת הבקרה הם נמוכים מ0.95 באופן מובהק.

התוצאות מוצגות בגרף 3' ובטבלה 3:

<u>גרף 3</u> - <u>דיוק תלמידי כיתה ג' בתרגילים מבוססי תוכנית לימודים בכיתה א'. כפונקציה של קבוצה.</u>



טבלה 4 - דיוק תלמידי כיתה ג' בתרגילים מבוססי תוכנית לימודים בכיתה א' כפונקציה של קבוצה. הבדלים מובהקים לאחר תיקון בנפרוני מסומנים בכתב מודגש.

	TD (n=43)		MD (n= 31)			
	Mean	*SD*	*Mean*	*SD*	*p*	*Cohen's D*
Subtraction	**0.93**	**0.17**	**0.72**	**0.29**	**.001****	**0.86**
Series	**0.95**	**0.14**	**0.67**	**0.24**	**.001****	**1.30**
Parity	**0.97**	**0.14**	**0.77**	**0.39**	**.004****	**0.71**
Number line estimation	0.87	0.22	0.81	0.18	.168	
Number line exact	0.98	0.07	0.95	0.15	.12	
Enumeration	**0.94**	**0.15**	**0.83**	**0.19**	**.02***	**0.64**
Counting	0.99	0.07	0.96	0.19	.235	
Comparison	0.94	0.16	0.93	0.17	.899	
Closer to number	0.92	0.19	0.86	0.17	.087	
Between numbers	**0.92**	**0.22**	**0.80**	**0.25**	**.029***	**0.51**
Addition	**0.98**	**0.07**	**0.89**	**0.18**	**.002****	**0.66**

מקרא *** מובהקות קטנה מ 001, * מובהקות קטנה מ05.

כל השאלות המסומנות בכתב מודגש מובהקות לאחר תיקון בנפרוני להשוואות מרובות.

מסקנות

- ילדים ללא קשיים הראו אחוזי דיוק מאד גבוהים בכל התחומים
- התחום היחיד שהראה הבדל מובהק מ0.95 דיוק זה הערכה של ציר מספרים שאיננה נלמדת בצורה מדויקת בבית הספר
- ילדים עם קשיים הראו ביצועים נמוכים במגוון מטלות אבל בהפרש קטן

המטלות שהראו אפקט הכי גדול היו חיסור וסדרות ובאפקט בינוני זוגי אי זוגי, מניה, מספר בין שני מספרים שונים וחיבור.

תוצאות בדבר תלמידים שלמדו מרחוק בכיתה ב'

בקבוצה של כיתה ד' בקבוצת הבקרה היו 54 ילדים, ובקבוצת המתקשים 53 .

אלו הן התוצאות

נמצא אפקט עיקרי לסוג התרגילים

$F(15,1575) = 30.87$, partial $\mu^2 = .23$, $p = .0001$.

נמצאה אינטראקציה בין סוג וקבוצה

.F)15,1575(= 17.01, partial μ² = .14, p =.0001

כל ההבדלים בין הקבוצות היו מובהקים. אולם בהשוואות ילדי הMD הראו דיוק רב יותר מילדי הTD.

ההבדלים בין הקבוצות היו עצומים הMD הראו קשיים ברוב הנושאים.

בחלק מהנושאים ילדי הMD הראו ביצועים נמוכים מ0.55%

כגון חיבור, מבנה עשרוני, משוואות, כפל, זוגיות, וחיסור.

ילדי הTD הראו ביצועים מצוינים בכל הנושאים פרט לחיסור (0.75) ומבנה עשרוני (0.87).

ראה טבלה 5

טבלה 5 - דיוק תלמידי כיתה ד' בתרגילים מבוססי תוכנית לימודים בכיתה ב'. כפונקציה של קבוצה. הבדלים מובהקים לאחר תיקון בנפרוני מסומנים בכתב מודגש.

		TD (n=54)	MD (n= 53)			
	Mean	*SD*	*Mean*	*SD*	*p*	*Cohen's D*
Addition	0.96	0.14	0.41	0.35	.001**	2.06
Changing unit decade	0.87	0.27	0.32	0.35	.001**	1.75
Comparison	*0.92*	*0.22*	*0.98*	*0.08*	*.05*	*0.36*
Create the biggest number	0.98	0.14	0.59	0.45	.001**	1.17
Create the smallest number	0.94	0.22	0.62	0.46	.001**	0.88
Estimation	0.94	0.17	0.57	0.41	.001**	1.17
Find a number	0.96	0.15	0.59	0.41	.001**	1.19
Equations	0.95	0.17	0.40	0.40	.001**	1.78
Multiplication	0.95	0.19	0.45	0.40	.001**	1.59
Multiplication rules	0.99	0.22	0.69	0.43	.001**	0.87
Number line exact	0.97	0.14	0.69	0.43	.001**	0.87
Number line estimation	0.96	0.10	0.85	0.28	.009*	0.52
Parity	0.96	0.15	0.48	0.41	.001**	1.61
Read number	0.96	0.15	0.73	0.42	.001**	0.72
Serious	1	0	0.63	0.45	.001**	1.15
Subtraction	0.75	0.33	0.23	0.34	.001**	1.551

A line represent significant differences from 0.95 for the TD group.

מקרא *** מובהקות קטנה מ 001, * מובהקות קטנה מ05. כל השאלות המסומנות בכתב מודגש מובהקות לאחר תיקון בנפרוני להשוואות מרובות.

<u>מסקנות</u>

הילדים שהיו בכיתה ב' במהלך הקורונה מראים קשיים רבים ביכולות היסוד.

הילדים מהקבוצה המתקשה מראים דיוק מאד נמוך, נמוך מ50% במגוון משימות חיבור, חיסור, שינוי עשרות ויחידות, כפל, זוגיות מספרית.

המשימה היחידה שבה הקבוצה עם הקשיים היא דומה לנבדקי בקרה היא השוואה של מספרים בטווח המאה.

לקבוצת הMD יש גם קשיים בכל היכולות האחרות אבל יש להם אחוזי הצלחה גבוהים יותר מרמת המקריות כלומר הם מראים הצלחה חלקית אך הבנה של הנושא והמשימה.

<u>מסקנות כלליות:</u>

- בעקבות ממצאי המחקר ניתן ללמוד כי תלמידים עם קשיים זקוקים לצמצום פערים במגוון תחומי היסוד במתמטיקה. כפי הנראה – לתלמידים אלה פער מובהק במיומנויות הבסיס, כלומר- שליטה בעובדות היסוד בחיבור, חיסור וכפל והבנת המהות של המבנה העשורי בתחום ה- 100, על כלל המיומנויות בתחום.
- ניתן ללמוד כי תלמידים ללא קשיים ראשוניים בתחום החשבוני הצליחו לצמצם את הפער בחלק ממיומנויות היסוד, לעומת תלמידים עם קשיים, אשר זקוקים להוראה ישירה ולתרגול עקבי בכדי לבסס מיומנויות אלה. אנו משערות כי ללא תמיכה ישירה ומשמעותית – תלמידים אלה ימשיכו להראות פערי ידע והבנה במתמטיקה.
- נקודה נוספת שעלתה במחקר היא שליטה טובה של תלמידים ללא קשיים בתחום עובדות הכפל, שנלמד לאחר תקופת ההוראה מרחוק. אנו מניחות כי השימוש בכלים דיגיטליים, שהתבסס ככל הנראה בתקופת הלמידה הווירטואלית- מחזק את השליטה במיומנויות הבסיס בקרב תלמידים לא מתקשים, אך אינו מספק קרקע לימודית מספקת ובלעדית לתלמידים מתקשים.

לסיכום- מחקר זה אפשר להכנס לעולם הידע המתמטי בקרב תלמידים מתקשים ולא מתקשים, שלמדו את אבני היסוד במתמטיקה בתקופת הקורונה. בהתאם להשערות המחקר, מצאנו כי תלמידים מתקשים מתעדים פערים לימודיים בכל מיומנויות היסוד, למעט השוואת מספרים בתחום ה-100.

בנוסף, תלמידים אלה אינם מצליחים להשלים את הפער, וזאת לעומת תלמידים ללא קשיים, שהראו התקדמות במיומנויות המתמטיות והישגיהם היו כמעט זהים לאלה שלפני עידן הקורונה בהקשר למיומנויות הבסיס.

נספח 1. מבחן השטף החשבוני למעלה בחיבור ולמטה בכפל. נבדקים היו צריכים לפתור כמה שיותר תרגילים נכונה בדקה בחיבור ואז היו צריכים לפתור את הכפל

התחילו פה →

6 + 9 =	1 + 7 =	1 + 6 =	1 + 8 =	4 + 3 =	1 + 2 =
8 + 7 =	9 + 4 =	5 + 3 =	7 + 7 =	8 + 2 =	6 + 3 =
4 + 7 =	6 + 5 =	6 + 8 =	1 + 9 =	7 + 3 =	3 + 7 =
7 + 2 =	9 + 6 =	8 + 6 =	1 + 5 =	6 + 4 =	5 + 2 =
9 + 8 =	5 + 6 =	3 + 9 =	4 + 2 =	7 + 8 =	8 + 3 =
8 + 4 =	8 + 9 =	1 + 4 =	2 + 7 =	9 + 1 =	2 + 6 =
3 + 4 =	3 + 5 =	3 + 1 =	4 + 6 =	6 + 1 =	4 + 5 =
1 + 1 =	8 + 8 =	5 + 4 =	7 + 4 =	5 + 9 =	2 + 2 =
8 + 1 =	8 + 5 =	7 + 5 =	3 + 6 =	6 + 6 =	7 + 1 =
9 + 3 =	2 + 9 =	6 + 7 =	2 + 4 =	3 + 3 =	5 + 1 =
4 + 4 =	9 + 5 =	7 + 9 =	4 + 8 =	2 + 8 =	9 + 7 =
3 + 2 =	9 + 9 =	4 + 1 =	3 + 8 =	7 + 6 =	1 + 3 =
2 + 5 =	5 + 5 =	5 + 8 =	2 + 3 =	4 + 9 =	9 + 2 =
2 + 1 =	6 + 2 =	5 + 7 =			

התחילו פה →

2x3 =	7x7 =	5x3 =	4x9 =	5x2 =	2x1 =
4x5 =	6x2 =	1x3 =	1x5 =	8x6 =	3x9 =
9x6 =	7x4 =	3x7 =	1x6 =	6x6 =	3x8 =
3x2 =	7x5 =	7x6 =	3x3 =	2x5 =	8x4 =
9x1 =	7x3 =	9x2 =	5x1 =	1x7 =	9x3 =
8x3 =	2x8 =	2x2 =	6x4 =	3x6 =	9x7 =
5x5 =	4x1 =	4x3 =	5x6 =	7x8 =	9x5 =
8x1 =	2x9 =	9x9 =	1x4 =	4x2 =	6x1 =
7x2 =	2x6 =	1x9 =	1x2 =	8x5 =	5x9 =
5x7 =	3x4 =	2x4 =	7x9 =	8x9 =	2x7 =
8x7 =	4x8 =	8x2 =	4x4 =	5x4 =	9x8 =
3x1 =	6x3 =	9x4 =	4x6 =	3x5 =	6x8 =
8x8 =	6x7 =	6x5 =	1x1 =	4x7 =	1x8 =
5x8 =	6x9 =	7x1 =			

נספח 2

Short-term and long-term effects of COVID-19 and remote learning: experiences of parents and teachers supporting children with a mathematical learning disability in Israel ראה מסמך מצורף

נספח 3

ראה מסמך מצורף

Dissociations between short and long-term effects of Corona closures:The case of math fluency

נספח 4

ראה מסמך מצורף

Short-term and long term effects of the coronavirus closure on multiple subject matters in mathematics

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נספח 1. מבחן השטף החשבוני למעלה בחיבור ולמטה בכפל. נבדקים היו צריכים לפתור כמה שיותר תרגילים נכונה בדקה בחיבור ואז היו צריכים לפתור את הכפל

התחילו פה →

6 + 9 =	1 + 7 =	1 + 6 =	1 + 8 =	4 + 3 =	1 + 2 =
8 + 7 =	9 + 4 =	5 + 3 =	7 + 7 =	8 + 2 =	6 + 3 =
4 + 7 =	6 + 5 =	6 + 8 =	1 + 9 =	7 + 3 =	3 + 7 =
7 + 2 =	9 + 6 =	8 + 6 =	1 + 5 =	6 + 4 =	5 + 2 =
9 + 8 =	5 + 6 =	3 + 9 =	4 + 2 =	7 + 8 =	8 + 3 =
8 + 4 =	8 + 9 =	1 + 4 =	2 + 7 =	9 + 1 =	2 + 6 =
3 + 4 =	3 + 5 =	3 + 1 =	4 + 6 =	6 + 1 =	4 + 5 =
1 + 1 =	8 + 8 =	5 + 4 =	7 + 4 =	5 + 9 =	2 + 2 =
8 + 1 =	8 + 5 =	7 + 5 =	3 + 6 =	6 + 6 =	7 + 1 =
9 + 3 =	2 + 9 =	6 + 7 =	2 + 4 =	3 + 3 =	5 + 1 =
4 + 4 =	9 + 5 =	7 + 9 =	4 + 8 =	2 + 8 =	9 + 7 =
3 + 2 =	9 + 9 =	4 + 1 =	3 + 8 =	7 + 6 =	1 + 3 =
2 + 5 =	5 + 5 =	5 + 8 =	2 + 3 =	4 + 9 =	9 + 2 =
2 + 1 =	6 + 2 =	5 + 7 =			

התחילו פה →

2x3 =	7x7 =	5x3 =	4x9 =	5x2 =	2x1 =
4x5 =	6x2 =	1x3 =	1x5 =	8x6 =	3x9 =
9x6 =	7x4 =	3x7 =	1x6 =	6x6 =	3x8 =
3x2 =	7x5 =	7x6 =	3x3 =	2x5 =	8x4 =
9x1 =	7x3 =	9x2 =	5x1 =	1x7 =	9x3 =
8x3 =	2x8 =	2x2 =	6x4 =	3x6 =	9x7 =
5x5 =	4x1 =	4x3 =	5x6 =	7x8 =	9x5 =
8x1 =	2x9 =	9x9 =	1x4 =	4x2 =	6x1 =
7x2 =	2x6 =	1x9 =	1x2 =	8x5 =	5x9 =
5x7 =	3x4 =	2x4 =	7x9 =	8x9 =	2x7 =
8x7 =	4x8 =	8x2 =	4x4 =	5x4 =	9x8 =
3x1 =	6x3 =	9x4 =	4x6 =	3x5 =	6x8 =
8x8 =	6x7 =	6x5 =	1x1 =	4x7 =	1x8 =
5x8 =	6x9 =	7x1 =			

נספח 2 מאמר שהוגש לפרסום

Dissociations between short and long-term effects of Corona closures: The case of math fluency in developmental dyscalculia and typically achieving children.

Sarit Ashkenazi[1*] and Sonia Hassoun[12]

Abstract

Over the last years, many studies have explored the effect of the Corona closures on learning and discovered that it resulted, mostly, in learning loss. However, studies that tested the long-term effects of the closures are lacking. Hence, the effects of the closures on the ability to solve addition or multiplication facts, in typically developing children and children with developmental dyscalculia were tested. A group of children that were in the 1st and 2nd grades during the closure were selected and were tested 2 years later. Another group of children with similar characteristics, before the closures (during 2018), served as the control group.

While addition facts were learned during the closure, multiplication facts were, mostly, learned after the closure. Concerning addition, typically developing children showed reduced ability after the closure. Interestingly, concerning multiplication, participants who were during the closures showed improved abilities. Children with developmental dyscalculia showed weakness in addition and multiplication but with more severe weakness in multiplication. These results indicated that learning loss is related to the time of acquisition of the subject matter. Addition, that was learned during the closures, resulted in a learning loss. Multiplication, which was learned after the closure, was not.

Keywords: Corona closure, developmental dyscalculia, mathematics, individual differences, mathematical fluency, arithmetical facts.

Dissociations between Short and Long-term Effects of Corona Closures: The Case of Math Fluency.

The coronavirus pandemic has led to drastic changes around the world generally, and in Israel specifically (Kaufman-Shriqui et al., 2022; Lee, 2020; Shahar et al., 2022). Schools were closed during the lockdown in the spring of 2020 in almost every country in the world. In Israel, specifically, the education system was closed from 2020 to 2021 between 11.5 to 24 weeks (Buonsenso et al., 2021). Even today, during the Gaza war in Israel many children, and young people, are still involved in distance learning. Distance learning has become a common solution to every situation where children cannot perform in-class learning. Hence, understanding the long-term effects of closure and distance learning on young children and learning mathematics, is very important both from educational and social perspectives. This question is particularly important for children who were in the 1st and 2nd grades during 2020 and needed to learn the basis of arithmetic during the closures. This age range is unique because: 1) the mathematical curriculum in the 1st and 2nd grades is the building block of later more complex mathematical knowledge (Haverty, 1999; Siegler, 2016), and 2) children as young as the 1st and 2nd grades cannot perform distance learning due to their inability to operate a computer by themselves, and concentrate for a full class.

The question about the effect of school closures on mathematics performance has already been tested around the world (Zierer, 2021). Kuhfeld et al. (2022) compared mathematical performances before and after the closures in the USA and found that both 3rd and 4th-grade mathematical performances decreased by 9 percentile positions for children after the closures, compared to before the

closures. Maldonado and De Witte (2022) looked at the effect of 7-week closures in Belgium, and found a decrease in the test values achieved in mathematics by 0.19 standard deviations. A meta-analysis that combined 12 studies regarding learning loss during the closures found that most of the studies reported learning loss to different degrees (Zierer, 2021). However, the results were highly heterogeneous. One of the explanations for the great heterogeneity in the effect of closures is individual differences, such as the presence of learning disabilities (Kadarisma & Juandi, 2021; Petretto et al., 2021; Poletti, 2020). Participants with learning disabilities are likely to be more heavily affected by the closures than their typically developing peers (Schuck & Lambert, 2020).

Independent of the Corona lockdown, multiple studies have tested the effect of remote online learning on participants with learning disabilities and found mixed results (Lee, 2020; Schuck & Lambert, 2020; Serianni & Coy, 2014; Sorensen, 2019). On the one hand, the advantage of online learning for participants with learning disabilities is free access to the course lectures and materials (Serianni & Coy, 2014). Moreover, online learning increases parents' awareness of the course materials, which is beneficial, especially for students with learning disabilities (Sorensen, 2019). On the other hand, previous studies mentioned a few points that can damage online learning in students with learning disabilities (Lee, 2020; Schuck & Lambert, 2020). Specifically, the online learning of students with learning disabilities requires great parental involvement, which might be a challenge to some of the parents (Schuck & Lambert, 2020). Moreover, students with learning disabilities need to use the support network of the school more than students without learning disabilities.

Hence, online learning disconnects the students from the school support network, affecting mostly students with learning disabilities (Lee, 2020).

The studies mentioned above looked at the effect of school closure on arithmetical abilities in general. However, the present study will examine a specific topic that is explicitly learned at the beginning of primary school: math facts (Boaler et al., 2015; Royer et al., 1999). Math facts are the ability to solve small math problems quickly and correctly (Boaler et al., 2015; Royer et al., 1999). Simple math problems are part of everyday activities. It helps to calculate how many candies you need for your kids' birthday or to calculate how many clothes to bring for a 6-day vacation. The ability to solve arithmetical facts was found to be a stable ability (Gliksman, Berebbi, & Henik, 2022; Gliksman, Berebbi, Hershman, et al., 2022; Petrill et al., 2012) and to predict math achievements throughout the primary school years (Durand et al., 2005; Russell & Ginsburg, 1984), and high school (Zentall, 1990).

Math facts are small addition and multiplication problems with operands from 1 to 10 that are learned mostly by rote memory, and retrieved automatically by the 4th grade. In Israel and other countries, the curriculum requires explicit training with math facts. In the 1st grade, the curriculum requires learning addition facts that sum up to a maximum of 20 numerical units. In the 2nd grade children train on addition facts and at the end of the 2nd grade multiplication facts are first learned as repeated addition. Please note, however, that schools differ greatly from one another, and most of the schools in Israel during the 2nd grade cover multiplication operations of only 1-5. Importantly, in the 3rd and 4th

grades the full multiplication table is taught, and in the 4th grade children should master all the math facts in addition and multiplication (Silverman et al., 2018).

In the initial stages of learning to solve mathematical problems, participants use backup calculation strategies that include counting or repetitive addition. With learning and practice, participants start using more advanced, memory-based strategies, including decomposition and direct retrieval. Advanced, memory-based strategies are faster and less error-prone than calculation and backup strategies. Hence, mastering arithmetical facts requires using memory-based strategies. Children with mathematical learning disabilities have persistent difficulties remembering basic arithmetic facts, and they continue using backup calculation strategies long after their typically developed peers. Their difficulty is more severe for large facts (e.g., 7 + 8) compared to small facts (e.g., 2 + 3) (Geary, 1990; Geary et al., 1991; Geary et al., 2007; Jordan et al., 2003; Ostad, 1997).

A popular way to examine mathematical fact knowledge is by using a math fluency test. A math fluency test includes multiple simple problems in addition or multiplication, and the subject needs to solve correctly as many problems as he/she can in one minute (e.g., (Gliksman, Berebbi, & Henik, 2022; Gliksman, Berebbi, Hershman, et al., 2022; Lockwood et al., 2023). To succeed in that task one needs to be both accurate and fast. Hence, only by using retrieval or decomposition strategies (that are very fast) can one can be faster and attain greater success in that task.

The Present Study

It has been documented that in most countries, the effect of the coronavirus pandemic has led to significant learning loss all across the world. However, the long-term effect of coronavirus closure on the ability to solve arithmetical facts has rarely been examined. Arithmetical facts are both learned explicitly at school and are one of the building blocks of more complex mathematics. In this study we selected children that were in the 1st and 2nd grade during the closure, and tested those children 2 years later during their 3rd and 4th grade. Children that were in the 1st and 2nd grade during the closures are a unique population because they were in their initial stages of learning arithmetic and were too young to fully participate in remote online learning.

We will test them on two math fluency tests: addition and multiplication. This will provide a unique window to test subject matters that were acquired during or after the closures. Specifically, additional facts were learned and practiced mostly during the closure. However, multiplication facts were mostly learned and practiced after the closure. Hence, the short-term effect of the closure will be reflected in addition facts knowledge, while the long-term effect of the closure should be reflected in multiplication facts knowledge. It will be interesting to test whether the closure will have a long-term effect on the mathematical subject matter that was learned after the closure. To understand the effect of the closures, we will compare the performances of children who were in their 3rd and 4th grade in 2018 before the Corona, to a group of participants who were in their 3rd and 4th grade during 2022-2023 and experienced the Corona closure in their 1st and 2nd grades. Another goal of the present study is to understand the effect of the coronavirus closure on students with learning disabilities. Hence, approximately half of the group of participants

that experienced the corona closure in their 1st or 2nd grades, were defined as a mathematical difficulties group (MD) due to severe difficulties in mathematics according to their teachers, and according to curriculum-based tests that were designed by the Ministry of Education, and half were typically developing (TD). We also selected a subgroup of participants that were diagnosed with developmental dyscalculia (DD) by a standardized test.

We believe that the group of children before Corona will show better performances in math fluency than the group of children that were in their 1st and 2nd grade during the Corona closures. The effect should be stronger for addition than multiplication. Among the children that were in their 1st and 2nd grade during the Corona, this effect should be stronger for participants with DD than for TD children.

Materials and Methods

Participants

2018 cohort

Three hundred ninety eight children from 3rd and 4th-grade students from 4 schools (Misgav, Irisim, Bialik, Korchac) in the northern district of Israel. 188 of them were from the 3rd grade (mean age = 8.79, S.D. =0.146) and 210 from the 4th grade (mean age = 9.91, S.D. =0.42). There were approximately the same number of females and males in that sample (55% females and 45% males). None of the participants had a diagnosis of learning disabilities.

2022 and 2023 cohorts

Group categorized

Defending the MD group

In the first step, we asked elementary school teachers from regular classes in the Northern District of Israel to select a group of children from the 3rd or 4th grade according to 1) Teacher assessment that they suffer from severe difficulties in mathematics. 2) According to achievements in mathematical curriculum-based tests in Israel (lowest 20%). The mathematical curriculum-based test was administered to all children in Israel during these years. Children who met these two criteria were defined as having mathematical difficulties (MD) group. We also asked the same elementary school teachers to provide us with an additional group of children with average or above-average performances in math. This group was defined as typically developing (TD).

Two hundred and nine children were selected from the 3rd and 4th grade, from 7 schools (4 were the same schools as in the 2008 cohort) in the northern district in Israel. 94 of them were from the 3rd grade, 34 were males (mean age = 8.64, S.D. =0.53) and 115 from the 4th grade, 47 were males (mean age = 9.83, S.D. =0.51). From the 3rd grade, 40 were TD and 54 were MD, from the 4th grade 48 were TD and 67 had severe difficulties in mathematical knowledge according to their teachers. The parents of all the participants signed a consent form for participation in the experiment. Two of the MD group participants did not complete all the tests and were excluded. One of the participants in the MD group quit during the experiment due to difficulties.

Defending the DD group

In the second step each of the participants that were defined as MD, performed 4 subtests from the KeyMath III diagnostic test, including numeration, estimation, written calculation addition and subtraction, written calculation multiplication, and division. We calculated the average standardized by-age score of the Key Math to classify participants into groups. Every participant with a standardized score of less than -1.2 SD equal to the lowest 12% of performances was entered into the developmental dyscalculia group (DD). Then we selected a subgroup from the TDs to serve as the control group for the current analysis. We found a subgroup of 23 children that met the criteria of DD from the 3rd grade and 23 matched controls (from the same class and sex) from the 3rd grade and 25 from the 4th grade and 25 matched controls (from the same class and sex).

Tools

Math fluency test

Participants begin with the addition subtest. 81 addition problems are presented on a sheet of paper (see Appendix 1) with operations between 1 to 9 including twins (the same digit twice). The test is completed by the all class together. The examiner puts the sheet of paper on the table and gives the following instructions: "Now I would like us to go over a few simple addition problems. Start here (the examiner points to the beginning point) and after finishing the line, move to the next line and solve every problem until you finish the page or the time is finished. If you do not know the answer to a specific

problem move to the next problem. Work as fast and accurately as you can, you have one minute. Tell me if you have finished before the minute is up. I will tell you when to stop. Are you ready? Start now."

Participants will then continue with the multiplication subtest. 81 multiplication problems are presented on a sheet of paper (see Appendix 1) with operands between 1 to 9 including twins. The test is administered to all participants together. The examiner sets the sheet of paper on the table and these are the instructions: "Now I would like us to solve a few simple multiplication problems. Begin here (the examiner points to the starting point), and after finishing the line move to the next line and solve every problem until you finish the page or the time is finished. If you do not know the answer to a specific problem, move to the next problem. Work as fast and accurately as you can, you have one minute. Tell me if you have finished before the minute is up. I will tell you when to stop. Are you ready? Start now."

Key Math III test

This was used only for the cohort of 2022- 2023. Mathematical abilities were assessed using KeyMath subtests: numeration, mental computation and estimation, addition and subtraction, and multiplication and division (Connolly, 1998). We chose KeyMath due to its comprehensive inclusion of several mathematics subtests, and our laboratory had translated it into Hebrew for previous studies (Silverman & Ashkenazi, 2022). In addition, since it is a standardized measure, it has high reliability (median subtest-retest reliability .88; (Connolly, 1998). The reliability between the subscales for the participants in the current study was very high (Cronbach's alpha = .90). The

items of each subtest are arranged in order of difficulty. The experimenter moves on to the next subscale after four consecutive errors or the end of the subscale. Numeration, mental computation, and estimation were conducted orally, with each item presented on the KeyMath easel, while addition and subtraction and multiplication and division were paper and pencil tests.

The numeration subtest includes 49 questions related to numerical understanding (place value, magnitude, number sense, decimals, fractions, percentages, exponents, integers, multiples, and factors). Mental computation and estimation, addition and subtraction, and multiplication and division are all part of the KeyMath area operations. Mental computation includes 40 items related to mental computation of whole and rational numbers, mental computation chains, and estimation of whole and rational numbers. Addition and subtraction include 35 items, and multiplication and division include 31 items. Both subtests ranged from basic operations with integers to algebra. All of the KeyMath subtests were given a raw score, the number of correct answers in addition to a standardized score according to class level. The KeyMath average score was used to classify participants into their developmental dyscalculia group.

Results

Accuracy before and after

Include a partial sample of the 2018 cohort

We included all the participants from the 2022-2023 cohort who did not suffer from difficulties in mathematics (TD). Those groups included 40 children in the 3rd grade and 48 children in the 4th grade. The cohort of 2018 is much larger and includes nearly 400 children. To equalize the number of children in each cohort a subgroup of children from the 2018 cohort were randomly selected for the current analysis: 40 3rd grade children and 48 4th grade children. A three-way repeated measures ANOVA was conducted on the number of correctly solved problems in 1 minute with the operation (multiplication or addition) as the within-participants factor and grade (3 or 4) and time (before or after) as the between-participants factor. The results of this ANOVA are summarized in Figure 1. The effect of class reaches significance $F(1,172) = 9.94$, partial $\eta^2 = .61$, $p = .007$. Children in the 4th grade ($M = 17.28$, $SD = 6.42$) correctly solved more problems than the 3rd-grade children ($M = 15.13$, $SD = 5.34$). The effect of time was marginally significant $F(1,172) = 3.12$, partial $\mu^2 = .02$, $p = .08$. The only significant interaction was between operation and time, $F(1,172) = 264$, partial $\mu^2 = .06$, $p = .002$. To understand the interaction we calculated an independent t-test for each of the operations. It was found that the pre-Corona group ($M = 20.54$, $SD = 7.96$) was more accurate in addition compared to the post-Corona group ($M = 12.53$, $SD = 4.87$) $t(147) = 7.69$, $p = .001$. However, the opposite trend was found for multiplication. It was found that the post-Corona group ($M = 19.1$, $SD = 5.85$) was more accurate compared to the pre-Corona group ($M = 14.06$, $SD = 5.96$). $t(174) = -5.67$, $p = .001$.

Include the whole sample of the whole cohort

Next, we compared the complete 2018 cohort to the group of children from the cohort of 2022-2023, whose teachers did not report that they suffer from mathematical difficulties. A three-way repeated measures ANOVA was conducted on the number of correctly solved problems in 1 minute with an operation (multiplication or addition) as a within-participants factor and grade (3 or 4) and time (before or after) as a between-participants factor. The effect of grade reached significance $F(1,474) = 24.39$, partial $\eta^2 = .05$, $p = .001$. The only significant interaction was between operation and time, $F(1,172) = 407$, partial $\mu^2 = .46$, $p = .001$. To understand the interaction we calculated an independent t-test for each of the operations. It was found that the pre-Corona group ($M = 19.7$, $SD = 7.56$) was more accurate in addition compared to the post-Corona group ($M = 12.67$, $SD = 5.17$). $t(181) = 10.52$, $p = .001$. However, the opposite trend was found for multiplication: the post-Corona group ($M = 19.1$, $SD = 5.85$) was more accurate compared to the pre-Corona group ($M = 13.3$, $SD = 5.86$). $t(476) = -8.37$, $p = .001$.

Accuracy for MD vs. Control for the cohort of 2022-2023 only

In the current analysis, we included only children who were in the 1st and 2nd grades during the Corona. First, we included the typically developing (TD) group, which according to their teacher had average school achievements, and the mathematical difficulty group (MD) which according to their teachers and curriculum-based measurements had severe difficulties in arithmetic. A three-way repeated measures ANOVA was conducted on the number of correctly solved problems in 1 minute with an operation (multiplication or addition) as the within-participants factor and grade (3 or 4) and group (MD or TD) as the

between-participants factor. The results of this ANOVA are summarized in Figure 2. The effect of grade reached significance $F(1,205) = 18.02$, partial $\eta^2 = .08$, $p = .001$. Children in the 4th grade ($M = 13.2$, $SD = 4.77$) solved more problems correctly than the 3rd-grade children ($M = 10.8$, $SD = 4.5$). The effect of group was also significant $F(1,205) = 176.5$, partial $\eta^2 = .46$, $p = .001$. TD Children ($M = 16.96$, $SD = 5.33$) solved more problems correctly than MD children ($M = 9.38$, $SD = 4.16$). The interaction between grade and group was marginally significant $F(1,205) = 3.813$, partial $\eta^2 = .018$, $p = .052$. The only significant interaction was between operation and group, $F(1,205) = 7.27$, partial $\mu^2 = .03$, $p = .008$. To understand that interaction, we calculated an independent t-test for each of the operations. We found that for both addition and multiplication TD children (addition- $M = 12.53$, SD = 4.87; multiplication- $M = 19.10$, SD = 5.8) solved more problems correctly than MD children (addition- $M = 6.12$, $SD = 4.11$; multiplication- $M = 10.85$, $SD = 4.37$) $t(208) = 10.22$, $p = .001$; $t(153) = 11.69$, $p = .001$, for addition and multiplication respectively. However, the difference was greater for multiplication (8.26) than for addition (6.56).

Accuracy for DD vs. Control for the cohort of 2022-2023 only

We selected subgroups of participants that according to a standardized measurement (KeyMath) were defined as DD and a matched control. A three-way repeated measures ANOVA was conducted on the number of correctly solved problems in 1 minute, with the operation (multiplication or addition) as a within-participants factor and grade (3 or 4) and group (DD or TD) as a between-participants factor. The results of this ANOVA are summarized in

Figure 3. The effect of grade reached significance $F(1,92) = 6.7$, *partial* $\mu^2 = .07$, $p = .011$. Children in the 4th grade ($M = 13.2$, $SD = 4.77$) solved more problems correctly than the 3rd-grade children ($M = 10.8$, $SD = 4.5$). The effect of group was significant, $F(1,92) = 84.79$, *partial* $\mu^2 = .48$, $p = .001$. TD Children (M = 16.96, SD = 5.33) solved more problems correctly than MD children ($M = 9.38$, $SD = 4.16$). The only significant interaction was between operation and group, $F(1,92) = 5.417$, *partial* $\eta^2 = .06$, $p = .022$. To understand this interaction, we calculated an independent t-test for each of the operations. It was found that for both addition and multiplication, TD children (addition- $M = 11$, $SD = 5.26$; multiplication- $M = 17.42$, $SD = 5.7$) solved more problems correctly than DD children (addition- $M = 4.29$, $SD = 4.09$; multiplication- $M = 8.48$, $SD = 4.08$) $t(94) = 6.98$, $p = .001$; $t(94) = 8.78$, $p = .001$, for addition and multiplication respectively. However, the difference was greater for multiplication (8.93) than for addition (6.7).

Correlation analysis for the cohort of 2022-2023 only

We conducted correlation analyses on all KeyMath subtests and math fluency tasks (addition and multiplication for the TD and MD groups (see Table 2)). First, in the two groups, multiplication fluency was positively associated with estimation and numeration KeyMath subtests ($r(122) = .40$, $p < .001$ and $r(122) = .39$, $p < .001$; $r(88) = .38$, $p < .001$ and $r(88) = .35$, $p < .001$ for MD estimation, MD numeration, TD estimation and TD numeration respectively). The correlation was not significantly different between the groups (minimum $p = .37$).

Second, in the two groups, addition fluency after Bonferroni correction was not significantly associated with estimation and numeration KeyMath subtests ($r(122) = .24$, $p < .01$ and $r(122) = .20$, $p < .05$; $r(88) = .31$, $p < .01$ and $r(88) = .27$, $p < .05$ for MD estimation, MD numeration, TD estimation and TD numeration respectively. The correlations were not significantly different between the groups (minimum $p = .39$).

Third, both addition and multiplication fluency were positively associated with the complex written calculation of addition and subtraction ($r(122) = .47$, $p < .001$; $r(122) = .35$, $p < .001$) and multiplication and division ($r(122) = .52$, $p < .001$; $r(122) = .51$, $p < .001$) in the MD group but not in the TD group ($r(88) = .14$, p = n.s.; $r(88) = .16$, p = n.s. and $r(88) = .08$, p = n.s. $r(88) = .2$, p = n.s. (For addition and subtraction with multiplication fluency and addition fluency and multiplication and division with multiplication fluency and addition fluency, respectively). All the differences in the correlations, except for the correlation between fluency addition and addition and subtraction in the KeyMath, (that was marginally significant, $p = 0.08$) were significant (minimum $p = .005$) (see Figure 4).

Discussion

The main goal of the present study was to test the long-term effect of coronavirus closure on the ability to solve arithmetical facts. Arithmetical facts are important building blocks of more complex mathematics, and are part of the mathematical curriculum. The population of the current study included children who were in the 1st and 2nd grade during the closure. We tested those children 3 years later during their 3rd and 4th grades. We compared their performances to a

group of children with similar characteristics that were during their 3rd and 4th grades in 2018, before the Corona closure.

Children who were in the 1st and 2nd grades during the closures are a unique population because they were in their initial stages of learning arithmetic during the coronavirus closure. For these children, addition facts were learned and trained mostly during the closure. However, multiplication facts were mostly learned and trained after the closure. As expected, concerning addition facts, children who learned them during the Corona closure showed reduced ability compared to children who learned it before the Corona. Interestingly, concerning multiplication facts, participants who were in the 1st and 2nd grades during the closures showed improved abilities compared to children before the coronavirus in 2018. One explanation for this is the increased usage of digital learning post-Corona. Online digital aids help in the rote memory of facts, such as multiplication.

Another important goal of the present study is to understand the effect of the coronavirus closure on students with learning disabilities. Students with learning disabilities are very vulnerable to changes such as the coronavirus closure. Hence, half of the group of participants who experienced the coronavirus closures were defined by their teachers to have severe deficits in mathematical processing. We found similar results for the whole group of participants according to teacher classification and for the group that was defined as DD according to standardized measurements. The two analyses discovered that children with severe deficits in mathematical processing reflect

weakness in addition and multiplication, but with more severe weakness in multiplication.

Last, correlation analysis discovered the DD but not TD group showed correlations between math fluency and complex written calculations. However, the two groups showed a correlation between basic numerical knowledge and math fluency and estimation and math fluency. Across groups, the correlations were stronger with multiplication fluency than with addition fluency.

Why do children who experienced the Corona closures show advanced abilities in multiplication compared to pre-Corona children?

Transformation of traditional learning environments into online learning scenarios occurred rapidly during the Corona closures, requiring teachers and students to acquire digital skills and competencies, implying the continuous implementation of educational innovations long after the Corona closures (Megahed & Ghoneim, 2022). The post-Corona pandemic increased the awareness of combined new approaches to face-to-face learning including blended learning methods (Cobo-Rendón et al., 2022). Blended learning is an instructional method that includes the efficiency and socialization opportunities of the traditional face-to-face classroom with the digitally enhanced learning possibilities of the online mode of delivery (Dziuban et al., 2004). Characteristics of this approach include (a) student-centered teaching where every student has to be actively involved in the content (b) increased opportunities for interaction between students and additional learning material (Hrastinski, 2019). A blended method comprises in-person sessions that are accompanied by online resources and tasks—essentially a combination of both

face-to-face and online learning. It had already been found that the blended method is better than traditional face-to-face learning for elementary school students' study of mathematics (Seage & Türegün, 2020).

We believe that online remote learning during the Corona closure introduced the opportunity to incorporate computer programs during the post-Corona learning process of mathematics. Hence, new subject matter, such as multiplication facts that were learned post-Corona, improved due to the intensive training in computer programs, because teachers and children became more familiar with blended learning methods that incorporated in-class and after class training with digital aides.

Weakness in the retrieval of arithmetic facts in DD: a specific deficit in multiplication

Persistent difficulties in memory of arithmetical facts is one of the diagnostic criteria of children with DD, according to the DSM-5 (American Psychiatric Association & Association, 2013). Importantly, children with DD are more consistently weaker at retrieving arithmetical facts from memory than at other aspects of arithmetic (Jordan & Hanich, 2000; Jordan et al., 2003; Jordan & Montani, 1997). Children with DD often rely on counting strategies more than on fact retrieval in arithmetic, long after their typically developing peers. The delay in the retrieval of arithmetical facts can be found long after the 3rd and 4th grades (Cumming & Elkins, 1999; Ostad, 1997; Russell & Ginsburg, 1984). Moreover, it was discovered that high school students with MD show severe deficits in math fluency tests, and their performances are matched to those of 2nd or 3rd grade typically developing children. Hence, in line with

previous studies, the current study discovered that children with severe deficits in arithmetic, according to their teacher, as well as participants who were defined as DD according to standardized measurement, showed deficits in math fluency. Importantly, the deficits of DD in multiplication were larger than in addition. Addition facts were learned and trained during the Corona closure. Hence, the TD and DD groups showed low performances in addition fluency. However, multiplication facts were learned and trained post-Corona and were actually better for TD children post-Corona compared to a group of children that was tested prior to the Corona, resulting in large group differences in multiplication.

Correlations between math fluency and complex mathematics: in MD and typically developing children

In previous studies, math fluency was found to be correlated to multiple complex mathematical abilities and to predict arithmetic abilities later on (Durand et al., 2005; Russell & Ginsburg, 1984; Zentall, 1990). In line with these findings, in the present study math fluency was significantly correlated in the two groups to 1) numeration, a subtest of the KeyMath III, that includes questions related to numerical understanding such as place value, magnitude, number sense, and to 2) estimation, a subtest of the KeyMath III, that includes non-written computational estimations, demonstrating that post-Corona basic fact knowledge is related to arithmetical understanding both for MD and TD. In addition, in the two groups, it was found that correlations between arithmetical understanding and multiplication were stronger than the correlations between arithmetical understanding and addition, demonstrating that the subject matter

that was learned post- Corona is more related to individual differences in arithmetical understanding than the subject matter that was learned during the Corona.

Only in the MD, but not in the TD group, was math fluency strongly correlated to achievements in written complex calculation. Mostly, mathematical fact and procedural knowledge deficits are dissociable, and written calculation tests procedural knowledge (Koponen et al., 2007). However, written calculation requires a solution of arithmetical facts and procedural knowledge. Because the DD group has severe deficits in the retrieval of arithmetic fact, they also have deficits in more complex written calculations, which results in the relation between math fluency and written calculation, only in the MD group.

Conclusion

Over the last three years, many studies have explored the effect of the Corona closures on learning, and discovered that it resulted mostly in learning loss. However, studies that tested the long-term effects of the closures on learning are lacking.

Hence, the main aim of the present study was to test the long-term effects of the closures on the ability to solve addition or multiplication facts, in TD and DD children. While addition facts were mostly learned and trained during the closure, multiplication facts were mostly learned and trained after the closure.

For TD, concerning addition, children who learned it during the Corona closure showed reduced ability, compared to children before the Corona closure.

Interestingly, concerning multiplication, participants who were in the 1st and 2nd grades during the closures showed improved abilities compared to children before the Corona. These results indicated that learning loss is related to the time of acquisition of the subject matter. In addition, as expected, we found learning loss. However, for multiplication, we found learning gains. The learning gain might be associated with a blended method comprised of in-person sessions that are accompanied by online resources and tasks, which have gained popularity post-Corona.

The DD post-Corona group showed weakness both in addition and multiplication, with a specific deficit in multiplication. This indicates that the greatest group differences emerge in the subject matter that showed a learning gain because of Corona closure in TD.

The present study provides a new perspective on the effect of Corona closures by revealing the complex effect of it on specific subject matters. The present study also points to dissociations between the short-term and long-term effects of Corona closures.

Table 1

Correlations between mathematical abilities tested by a standardized measurement (KeyMath III) and mathematical fluency by operation and group.

	Fluency Multiplication			Fluency Addition		
	MD(n=122)	TD (n= 88)	Diff	MD(n=122)	TD (n= 88)	Diff
Fluency Addition	**.53*** **	**.52*** **	.46			
KeyMath AS	**.47*** **	**.**14	**.005**	**.35*** **	.16	.08
KeyMath MD	**.52*** **	.08	**>.001**	**.51*** **	**-**.02	**>.001**
KeyMath Estimation	**.40*** **	**.38*** **	.43	.24**	.31**	.29
KeyMath Numeration	**.39****	**.35*** **	.37	.20*	.27*	.30

Note. * p< .05, ** p<.01 *** p < .001, bold font represents significance after bonferoni correction (p < .003). AS= addition and subtraction; MD= multiplication and division.

Figure Captions

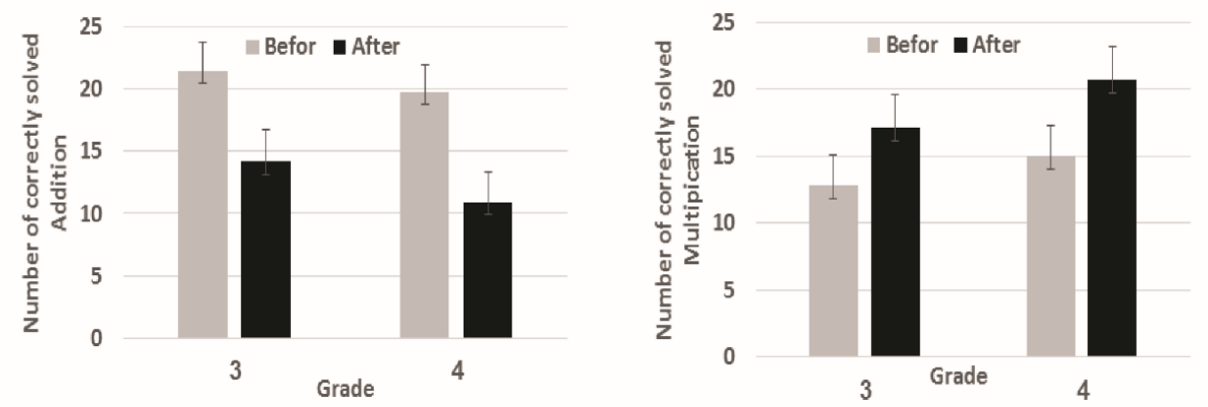
Figure 1. The number of correctly solved problems in math fluency tasks as a function of grade level and time before or after the coronavirus closures. It was found that the group before the coronavirus was more accurate in addition compared to the group after. However, the opposite trend was found for multiplication, where it was found that the post-Corona group was more accurate compared to the pre-Corona group.

Figure 2. The number of correctly solved problems in a math fluency task as a function of grade level and group (TD, MD): all of the participants in the current analysis were in their 1st and 2nd grade during the Corona closure. It was found that the pre-Corona group was more accurate in addition compared to the post-Corona group. However, the opposite trend was found for multiplication: it was found that the post-Corona group was more accurate compared to the pre-Corona group. It was found that for both addition and multiplication, TD children solved more problems correctly than MD children. However, the difference was greater for multiplication than for addition.

Figure 3. The number of correctly solved problems in a math fluency task as a function of grade level and group (TD, DD): all of the participants in the current analysis were in their 1st and 2nd grade during the Corona closure. It was found that the pre-Corona group was more accurate in addition compared to the post-Corona group. However, the opposite trend was found for multiplication, where it was found that the post-Corona group was more accurate compared to the pre-Corona group. It was found that for both addition and multiplication, TD children solved more problems correctly than DD children. However, the difference was greater for multiplication than for addition.

Figure 4. Correlation between multiplication fluency and complex addition and subtraction ability (top part) or multiplication and division (bottom part) and group (TD, MD): all of the participants in the current analysis were in their 1st and 2nd grade during the Corona closure. It was found that the correlations were significant in the MD group, but not in the TD group.

Figure 1.


Number of correctly solved Addition
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Number of correctly solved Multipication
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Grade

Figure 2.

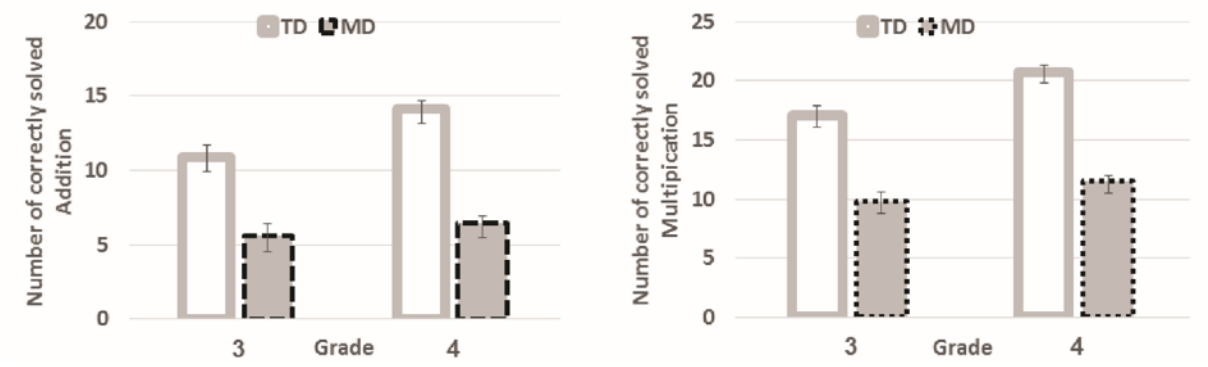

Number of correctly solved Addition
20
15
10
5
0
TD
MD
3
Grade
4
Number of correctly solved Multipication
25
20
15
10
5
0
TD
MD
3
Grade
4

Figure 3.

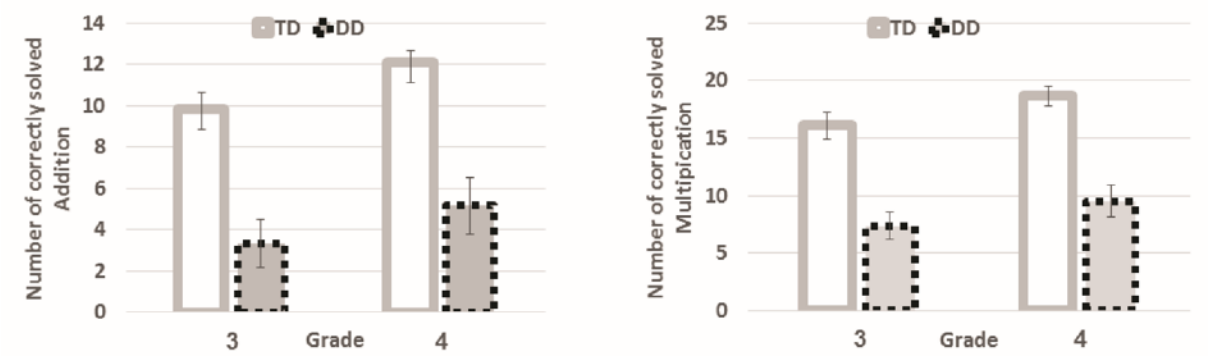
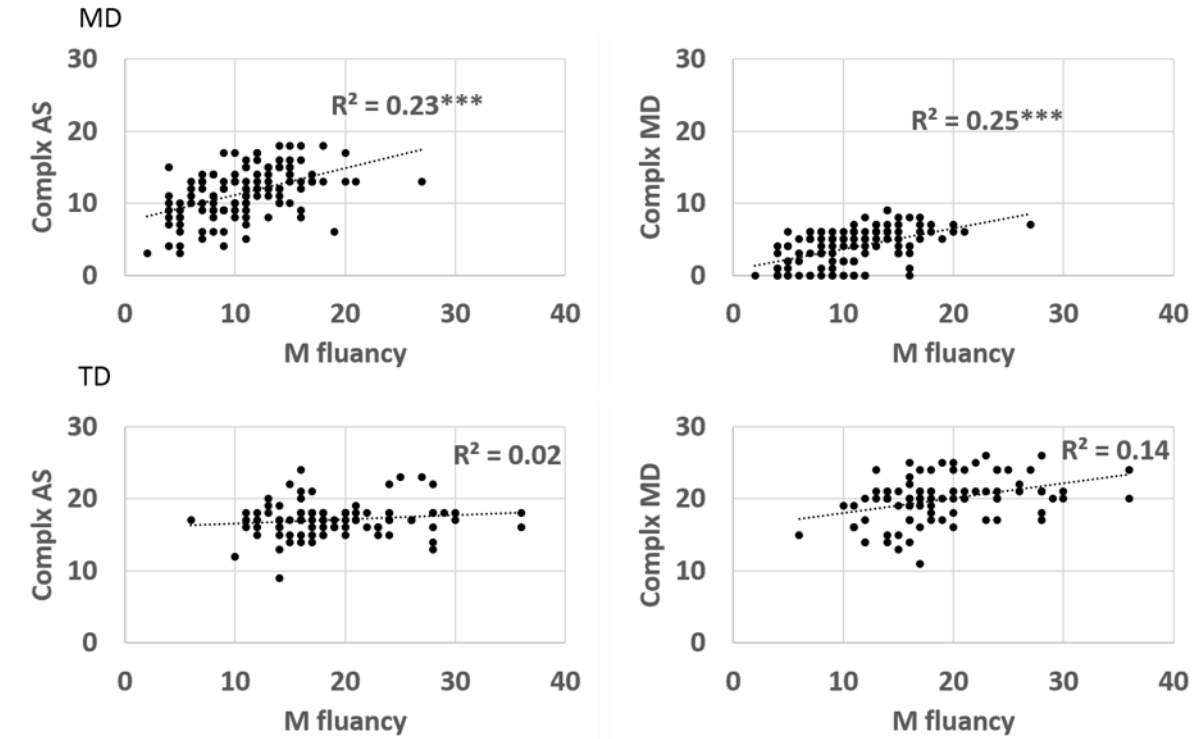

Number of correctly solved Addition
14
12
10
8
6
4
2
0
TD
DD
3
Grade
4
Number of correctly solved Multipication
25
20
15
10
5
0
TD
DD
3
Grade
4

Figure 4.


MD
Complx AS
M fluancy
R² = 0.23***
Complx MD
M fluancy
R² = 0.25***
TD
Complx AS
M fluancy
R² = 0.02
Complx MD
M fluancy
R² = 0.14

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נספח 3 מאמר 2 שנשלח לפרסום

Article.

Short-term and long-term effects of COVID-19 and remote learning: experiences of parents and teachers supporting children with a mathematical learning disability in Israel.

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Abstract: (1) Background: Over the last three years, many studies have explored the effect of the pandemic closures on learning. However, in Israel, the perspectives of parents and teachers on the short- and long-term effects of the lockdowns on students with mathematical learning disabilities (MD), have rarely been examined. (2) Methods: To fill this gap, MD (n= 33) or typically developing (n=50) children were selected. They were in the 1st and 2nd grades during the closures, and we tested them and their surroundings, two years later.; (3) Results and conclusion: First, according to the parent's survey, children with MD had physical conditions similar to the TD group, the two groups had similar stable connections to the internet, computer, and a quiet environment. However, MD children 1) needed more help and 2) had a harder time concentrating during virtual math classes compared to TD children. Moreover, the coronavirus closures resulted in a greater learning gap in the MD children compared to the TD children. We found positive associations between difficulties reported by the parents and actual weakness in performances in complex multiplication and division and verbal working memory. Second, according to the teachers' survey (n = 15), we discovered that teachers are currently using more digital aids than before the coronavirus closure.

Keywords: long-term effect of coronavirus closure, mathematical learning disabilities, perspectives of parents, perspectives of teachers, individual differences.

1. Introduction

The coronavirus pandemic has led to drastic changes around the world generally, and in Israel specifically [1-3] . Schools were closed during the lockdown in the Spring of 2020 in almost every country in the world. In Israel, specifically, the education system was closed from 2020 to 2021 between 11.5 to 24 weeks [4]. Even today, during the Gaza War in Israel, many children and young people are still involved in distance learning. Distance learning has become a common solution to every situation where children cannot participate in in-class learning. Hence, understanding the perspectives of parents and teachers about the short- and long-term effects of closure and distance learning on young children with mathematical learning disabilities is very important from both the educational and social perspectives. This question is particularly important for children who were in the 1st and 2nd grades during 2020 and needed to learn the basics of arithmetic during the closures. This age range is unique because: 1) the mathematical curriculum in the 1st and 2nd grades is the building block of later, more complex mathematical knowledge [5, 6], and 2) children as young as the 1st and 2nd grades cannot perform distance learning independently, due to their difficulties in operating a computer by themselves, and concentrating throughout a full class period.

The question about the cognitive effects of school closures on children with and without learning disabilities has already been tested around the world [7]. Kuhfeld, et al. [8] compared mathematical performances before and after the closures in the USA and found that both 3rd and 4th-grade children's mathematical performances decreased by 9 percentile points after the closures, as compared to before the closures. Maldonado and De Witte [9] looked at the effect of 7-week closures in Belgium and found a 0.19 standard deviation decrease in the test values achieved in mathematics. A meta-analysis that combined 12 studies regarding learning loss during the closures found that most of the studies reported varying degrees of learning loss [10]. However, results were highly heterogeneous. One of the explanations for this great heterogeneity in the effect of closures is individual differences, such as the presence of learning disabilities [11-13]. Participants with learning disabilities are likely to be more heavily affected by the closures than their typically developing peers [11-14].

Independent of the Corona lockdown, multiple studies have tested the effect of remote online learning on participants with learning disabilities and found mixed results [3, 14-16]. On the one hand, the advantage of online learning for participants with learning disabilities is free access to the course lectures and materials [16]. Moreover, online learning increases parents' awareness of the course materials, which is beneficial, especially for students with learning disabilities [15]. On the other hand, previous studies have mentioned a few points that can interfere with online learning in students with learning disabilities [3, 14]. Specifically, the online learning of students with learning disabilities requires great parental involvement, which might be a challenge for some of the parents [14]. Moreover, students with learning disabilities need to use the support network of the school more than students without learning disabilities. Hence, online learning disconnects the students from the school support network, affecting mostly students with learning disabilities [3].

Incorporating digital aides into post lockdown classes

Transformation of traditional learning environments into online learning scenarios occurred rapidly during the pandemic closures, requiring teachers and students to acquire digital skills and competencies, implying the continuous implementation of educational innovations long after the pandemic closures [17, 18] . The post-Corona pandemic increased the awareness of combined new approaches to face-to-face learning, including blended learning methods [19]. Blended learning is an instructional method that includes the efficiency and socialization opportunities of the traditional face-to-face classroom with the digitally enhanced learning possibilities of online modes of delivery [20]. Characteristics of this approach include (a) student-centered teaching where every student has to be actively involved in the content (b) increased

opportunities for interaction between students and additional learning material [21]. A blended method comprises in-person sessions that are accompanied by online resources and tasks—essentially a combination of both face-to-face and online learning. It has already been found that the blended method is better than traditional face-to-face learning for elementary school students' study of mathematics [22]. However, the question of whether post Corona classrooms incorporated blended methods more than pre-Corona classrooms has yet to be determined.

Environmental perspective on distance learning during COVID-19

A few previous studies have explored parents' and teachers' perspectives on distance learning during the COVID-19 pandemic [23-27]. Stites, Sonneschein and Galczyk [27] examined parents' perspectives in the US and found that parents were more involved in literacy-based activities than in mathematics activities. Additionally, the surveyed parents stated that time was a significant factor in helping their children with distance learning and expressed a preference for activities that didn't require a lot of time. Later, Godwin, Kaur and Sonnenschein [24] tested the viewpoints of parents and teachers regarding remote learning for elementary school children during the pandemic. Teachers reported that the amount of virtual instruction was less than in-person instruction and that children were more off-task. In addition, parents reported that fewer than half of the children completed online lessons independently. Furthermore, parents reported that children preferred in-person learning over online learning. Other studies investigated the perspectives of parents of children in special education and found that these children were unable to participate in virtual learning without significant adult support. Parents often had other responsibilities and were unable to provide their children with assistance during virtual learning [25, 26].

The Present Study

It has been documented that in most countries, the effect of the coronavirus pandemic has led to significant universal learning loss. However, in Israel, the multiple perspectives of parents and teachers on the short- and long-term effects of the lockdowns on students and classes with students with learning disabilities, have rarely been examined [23-27]. In this study, we selected children that were in the 1st and 2nd grade during the closures and tested those children 2 years later during their 3rd and 4th grades. Children who were in the 1st and 2nd grades during the closures are a unique population because they were in their initial stages of learning arithmetic and were too young to fully participate in remote online learning. We selected a group of typically developing children (TD) and a group of children with mathematical learning disabilities (MD). The MD

group was defined due to severe difficulties in mathematics according to their teachers, and according to curriculum-based tests that were designed by the Ministry of Education in Israel. In addition to their performances on multiple mathematical and domain-general tasks, we collected online surveys from their parents and teachers.

Whilst most of the studies described above focused on the national lockdown period, little is known about parental views on remote learning during the lockdown. The first study aimed to ascertain the impact of the COVID-19 pandemic on the learning process of children with mathematical learning disabilities in Israel, from the parents' point of view, with a focus on experiences of school closures. To achieve this goal, the following research questions were formulated: 1) How did parents of children with learning disabilities perceive the impact of school closures on their children's abilities to learn math later on, and whether there are differences between parents' perceptions of children with or without learning disabilities? 2) Whether parent's perceptions about difficulties during the lockdownsare associated with specific subject matter in the mathematical abilities of their child? 3) Whether parent's perceptions of difficulties during the lockdowns are related to specific domain-general abilities associated with their child's learning?

We believe that parent's perceptions of difficulties during the lockdown will be more severe in children with mathematical learning disabilities (MD) than in typically developing children (TD). Moreover, based on previous studies, our expectation relates to parents of children with learning disabilities who reported that they need more help than parents of typically developing children [14]. We believe that parents of MD children will report that they need more help than parents of TD children. Moreover, based on our previous findings, from the same population, we found that MD children have more meaningful weaknesses in multiplication than in addition. We believe that perceived difficulties related to the closures will be associated with real performances in multiplication.

Moreover, little is known about the long-term effect of the lockdown on teachers' instructional methods. Hence, the goal of Study 2 was to examine the effect of the lockdown on teachers' instructional methods. In a recent study (Ashkenazi et al., submitted), we discovered that in multiplication facts, that were learned after the Corona period, post-Corona lockdown TD children showed better performances than children before the Corona. We believe that the Corona lockdown forced the teachers to use online or hybrid learning methods, that incorporated digital aids during and outside class. These new methods with digital aids potentially explain the improvements of children in subject matters that were learned after the lockdowns. Accordingly, we hypothesized that teachers post-Corona are using more digital aids that improve multiplication

training. Hence, in Study 2 we selected the teachers of the same children as in Study 1, who had practiced teaching before and after the Closures, and asked them to use the online survey about their classrooms and digital aids post and pre-corona. We believe that teachers would report that they are using digital aids more frequently post-Corona compared to pre-Corona. This will be evident in all mathematics subject matter and both in and outside class.

2. Experiment 1

The present study employs a survey design to assess parental perspectives on the impact of school closures in Israel, as a result of the Covid-19 pandemic. Data was collected between October and December 2022- 2023 following ethical approval by the Ethics Committee of the host higher educational institution. All data was anonymous and informed consent was obtained from respondents before initiating the survey. Table 1 presents the full items and average responses by groups.

2.1 Materials and Methods of experiment 1

2.1.1 Participants

In the first step, we asked elementary school teachers from regular classes in the Northern District of Israel to select a group of children from the 3rd or 4th grade according to 1) Teacher assessment that they suffer from severe difficulties in mathematics, and 2) According to achievements in mathematical curriculum-based tests in Israel (lowest 20%). The mathematical curriculum-based test was administered to all children in Israel during these years. Children who met these two criteria were defined as belonging to the mathematical difficulties (MD) group. We also asked the same elementary school teachers to provide us with an additional group of children with average or above-average math performances. This group was defined as typically developing (TD).

Eighty-three children were selected from the 3rd and 4th grades, from 7 schools in the Northern District of Israel. 34 of them were from the 3rd grade, 16 were males (mean age = 8.64, S.D. =0.53) and 46 from the 4th grade, 21 were males (mean age = 9.83, S.D. =0.51). From the 3rd grade, 17 were TD and 20 were MD, from the 4th grade 16 were TD, and 30 had severe difficulties in mathematical knowledge according to their teachers. The parents of all the participants signed an informed consent form for participation in the experiment. The study was approved both by the ethics committee of the Education Ministry and the School of Education at the Hebrew University. Two of the MD group participants did not complete all the tests and were excluded. One of the participants in the MD group quit during the experiment due to difficulties.

2.1.2 Tools

Domain general and domain specific general tasks.

2.1.2.1 Math fluency test

Participants start with addition and then continue with the multiplication subtest. 81 multiplication and 81 addition problems are presented on a sheet of paper with operands between 1 to 9 including twins. The test is administered to all participants together.

2.1.2.2 Key Math III test

Mathematical abilities were assessed using KeyMath subtests: numeration, mental computation and estimation, addition and subtraction, and multiplication and division [28]. We chose KeyMath due to its comprehensive inclusion of several mathematics subtests, and our laboratory had translated it into Hebrew for previous studies [29]. In addition, since it is a standardized measure, it has high reliability (median subtest-retest reliability .88; [28]. The reliability between the subscales for the participants in the current study was very high (Cronbach's alpha = .90). The items of each subtest are arranged in order of difficulty. The experimenter moves on to the next subscale after four consecutive errors or the end of the subscale. Numeration, mental computation, and estimation were conducted orally, with each item presented on the KeyMath easel, while addition and subtraction and multiplication and division were paper and pencil tests.

The numeration subtest includes 49 questions related to numerical understanding (place value, magnitude, number sense, decimals, fractions, percentages, exponents, integers, multiples, and factors). Mental computation and estimation, addition and subtraction, and multiplication and division are all part of the KeyMath area operations. Mental computation includes 40 items related to mental computation of whole and rational numbers, mental computation chains, and estimation of whole and rational numbers. Addition and subtraction include 35 items, and multiplication and division include 31 items. Both subtests ranged from basic operations with integers to algebra. All of the KeyMath subtests were given a raw score, the number of correct answers in addition to a standardized score according to class level. The KeyMath average score was used to classify participants into their developmental dyscalculia group.

2.1.2.3 Nonstandardized basic numerical tasks

Simple operations RTs. Simple addition, multiplication, and subtraction operations were shown to the participants on the screen, and the participants were instructed to give a vocal response to the operation. RTs of the correct trail served as the dependent variable.

Comparison is symbolic. Two digits between 1 to 9 were presented on the screen in two sizes and the participants were instructed to ignore the physical size and select, by a keypress, the larger digits. Numerical distance (1 and 4) and physical size resulting in 3 congruity conditions (congruent, natural, and incongruent) were manipulated; the dependent measure was average RTs for correct trials. A typical trial started with a fixation cross for 500 ms and then the digits appeared until the response, and ended in a blank screen for 500 ms.

Comparison Non-symbolic. Participants were presented with dots, ranging between 5 and 24, in various sizes, the participants had to indicate by a key press, in which size there are more dots and ignore their physical size. A typical trial started with a fixation cross for 300 ms and then a blank screen for 500 ms, then the dots appeared until the response and ended in a blank screen for 1500 ms.

2.1.2.4. Domain general abilities

Vocabulary. Twenty-three words were presented to the child verbally and they were instructed to say what the meaning of this word is. Every meaning got a score between 0 to 2.

Visuospatial short-term and working memory. A computerized version of the Corsi block test was used to measure the participant's spatial working memory span. Nine blue squares (2 cm × 2 cm) were unevenly distributed over a 16 cm × 16 cm quadrant on a computer screen. The positions of the squares were fixed. Each trial began with the presentation of nine blue squares, and then a random sequence of squares was lit up in yellow at a rate of one square per second. The squares remained on the screen for 500 ms after the sequence was completed. Then a black screen was presented for 15 seconds. Finally, the nine blue squares were presented again and the participant had to reproduce by mouse click the sequence in which the squares had lit up, either in the same order (working memory) or in the reverse order (central executive). (Task from the Psychology Experiment Building Language- PEBL).

2.1.2.5. Verbal short-term and working memory

A computerized version of the digit span test was used to measure the participants' phonological span. In each trial, a sequence of numbers was auditorily presented to the participants. The participants were asked to repeat the sequence numbers in the same order (working memory) or reverse order (central executive). Trials started with a sequence of two numbers and increased in difficulty with each successive trial. In contrast to the phonological span test, which involves the use of non-numerical stimuli (letters), the present task used digits.

Inhibition. A row of 5 fishes were presented on the screen and the participants had to indicate by a keypress whether the

central fish is pointing to the left or the right, and ignore the fisheson the sides. In the congruent condition, all the fishes were pointing in the same direction, in the incongruent condition the central fish was pointing to the opposite location compared to the fishes on the sides. A typical trial started with a fixation cross for 500 ms and then the digits appeared until the response and ended in a blank screen for 500 ms.

Processing speed. In the tasks participants were presented with the number 1 to 9 that matched 9 abstract symbols, e.g., the number 1 was matched to that abstract symbol . the matching between the 9 numbers and symbols were on the screen for the whole experiment. During the experiment, participants were shown a pair of a number and a symbol and had to indicate, by a key press whether the symbol matched the number or not.

Raven. Children were shown 37 trials with a pattern with a missing part they should indicate to select the part that is missing from a few options. Dependent variable was accuracy.

Parent's survey- the influence of remote learning during the Corona period. The survey included 14 items. The survey was sent online and the general instructions for the parents were "your child was in his first or second grade during the Corona period, try to remember the closures time two years ago, when your child performed virtual learning. Try to answer the questions as exactly as possible. For every item, please decide which ranking best describes the remote learning period during the closures. Please answer with a score of 1- not at all, to 5 - very much. Please mark only one answer. Please work fast, but relate to every item separately. The individual items are presented in Table 1.

Table 1 *Results of all the questions for all the groups*

	The translated question	TD (n=50)		MD (n= 33)		
		Mean	*SD*	*Mean*	*SD*	*p*
Q1	**The student was able to keep track of what was going on during class**	**3.58**	**11.09**	**33.09**	**11.09**	**..004***
Q2	The student was able to understand the teacher	3.50	11.09	33.24	00.87	..25
Q3	It was harder for the student to study in a virtual compared to a frontal class	3.26	11.12	33.85	11.29	..06
Q4	Digit learning aids, including short movies, helped the student understand the subject matter	3.65	11.12	33.38	00.98	..25
Q5	**It was hard for the student to concentrate during virtual math class**	**3.06**	**11.23**	**33.82**	**11.13**	**..006****
Q6	It was hard for the student to find symbols on the keyboard	2.51	11.18	33.06	11.41	..07
Q7	The student performed the tasks that were given to him/her on time	3.88	11.24	33.42	11.09	..09
Q8	**The student had a hard time performing the online task by himself and without help from others**	**2.95**	**11.26**	**44.00**	**11.06**	**..001****
Q9	The student always had a quiet and isolated environment during online learning	3.38	11.26	33.27	11.35	..71
Q10	The student always had the computer available for learning	4.04	11.21	44.15	11.18	..68
Q11	The student left the online lesson only when it ended	4.33	00.77	44.15	11.23	..43
Q12	The student used a mobile phone instead of the computer during learning	2.16	11.35	11.94	11.34	..47
Q13	The student had a stable connection to the interment during online classes	3.90	00.95	33.94	11.20	..87
Q14	**The Corona period resulted in significant learning gaps for the student**	**3.51**	**10.97**	**44.15**	**11.26**	**..02***

* p< .05, ** p<.01 *** p < .001, bold font represents significance after Bonferoni

2.2. Results of experiment 1

2.2.1 Preliminary Analysis

Reliability Analysis. The questionnaire included 14 items. In order to test the Reliability of the test we calculated Cronbach's Alpha. With all of the 14 items Cronbach's Alpha was rather low (.38). In order to increaseit we first omitted Q2, Q4 and Q12 to receive Cronbach's Alpha = .58, then we omitted Q7 to receive Cronbach's Alpha = .63, then we omitted Q10 and Q11 to receive

Cronbach's Alpha =.71, then we omitted Q9 and Q13 to receive Cronbach's Alpha = .82. Then only 6 items were left: Q1, Q3, Q5, Q6, Q8 and Q14.

Factor Analysis. Exploratory factor analysis (EFA) was performed on the correlation matrix in order to identify underlying dimensions (factors) as measured by 6 items comprising the Parent's survey- the influence of remote learning during the Corona period that found to be with high Reliability. We used principle axis factoring method. The results indicated a single factor with an Eigenvalue of greater than 1, that explained 52.61% of the variance with direct Oblimin. The results are presented in Table 1. The model fit indices obtained through EFA for the one-factor were: $\chi 2/df = 10.46$, Kaiser-Meyer-Olkin measure of sampling adequacy = .77, Bartlett's test of sphericity p = .001. Thus, the one-factor model was acceptable.

2.2.2 Main Analysis

Group Comparison of Responses. In the current analysis, we included the typically developing (TD) group, which according to their teacher had average school achievements, and the mathematical difficulty group (MD) which according to their teachers and curriculum-based measurements had severe difficulties in arithmetic. A three-way repeated measures ANOVA was conducted on the response with item numbers (1-14) as the within-participants factor and grade (3 or 4) and group (MD or TD) as the between-participants factor. The effect of item was significant $F(13,962) = 16.44$, partial $\mu^2 = .182$, $p = .001$. The interaction between group and item was also significant $F(13,962) = 4.157$, partial $\mu^2 = .053$, $p = .001$. Accordingly, we tested group differences in each item. The results are summarized at Table 1. First, according to Q1, in medium effect size, parents of children from the MD group reported that they had a harder time following a virtual class compared to parents of children from the TD group. Second, according to Q5, in medium effect size, parents of children from the MD group reported that they had a harder time concentrating in a virtual math class compared to parents of children from the TD group. Third, according to Q8, in large effect size, parents of children from the MD group reported that they had a harder time performing their virtual learning tasks without help, compared to parents of children from the TD group. Fourth, according to Q14, in medium effect size, parents of children from the MD group reported that the Corona closure resulted in larger learning gaps compared to parents of children from the TD group.

Responses by Group for Only 6 Reliable Items. A three-way repeated measures ANOVA was conducted on the response with item numbers (1, 3, 5, 6, 8, 14) as the within-participants factor and grade (3 or 4) and group (MD or TD) as the between-participants factor. The effect of item was significant $F(5, 385) =$

7.81, partial $\mu^2 = .09$, $p = .001$. The interaction between group and item was also significant $F(5, 385) = 4.897$, partial $\mu^2 = .06$, $p = .001$. The results are summarized in Table 3. All of the questions that showed significant group differences were included in the current analysis, hence, we did not analyze the group by item interaction (see the previous section).

Table 3 *Results of the items only according to relatability analysis*

	TD (n=50)		MD (n= 33)		p	Cohen's d
	Mean	*SD*	*Mean*	*SD*		
Q1	**3.58**	**1.01**	**3.09**	**1.10**	**.04***	-0.47
Q3	3.26	1.43	3.85	1.28	.06	
Q5	**3.06**	**1.25**	**3.82**	**1.13**	**.006****	0.64
Q6	2.51	1.21	3.06	1.43	.07	
Q8	**.95**	**1.26**	**4.00**	**1.06**	**.001****	0.90
Q14	**.51**	**1.34**	**4.15**	**1.03**	**.02***	0.54

Correlation Analysis between Responses, Domain General, and Mathematical Abilities. We conducted correlation analyses between responses in the questionnaire that showed significant group differences, and domain general and domain specific factors. First, we tested the relations between general abilities and average score in the items that showed significant group differences in the previous analysis. The scores of Q1 were coded as opposite scores (results of 1 were coded as 5, results of 2 were coded as 4, results of 4 were coded as 2 and results of 5 were coded as 1) and then the opposite scores of Q1 were averaged together with Q5, Q8 and Q14 (see Table 1). Table 3 presents the correlation between these scores and general abilities. It was found that only verbal working memory was negatively associated with response in the questionnaire, $r(62) = -.43$, $p < .001$ (see Figure 1). Table 4 presents the correlation between these scores and numerical and mathematical abilities. It was found that after Bonferroni correction, only KeyMath multiplication and division was negatively associated with responses in the questionnaire, $r(62) = -.35$, $p < .01$ (see Figure 1).

Table 4 *Results of the items only according to relatability analysis*

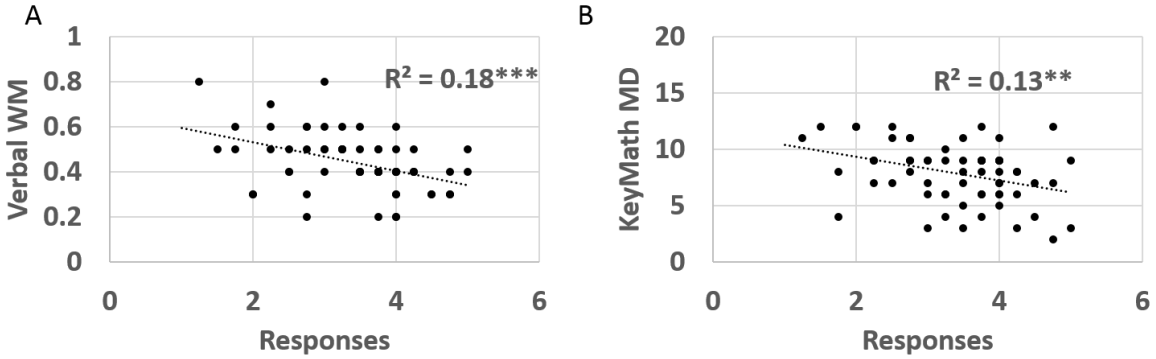
Test	Correlation	Significant
Vocabulary	-.01	.92
Visuospatial short-term memory	.05	.97
Visuospatial working memory	-.05	.72
Verbal short-term memory	-.01	.95
Verbal working memory	**-.43**	**.001**
Inhibition	.13	.25
Processing speed	.12	.38
Revan	-.19	.13

Note. Bold font represents significance after Bonferoni correction ($p < .006$).

Note. Bold font represents significance after Bonferoni correction ($p < .006$).

Figure 1

Correlations between responses in the items that showed significant differences between MD and TD groups and verbal working memory score (left part) or complex multiplication and division tested by the keymath score (right part). The result showed significant and positive correlation between parents' report and actual weakness in complex calculation and verbal working memory.



2.3. Discussion of experiment 1

The main aim of this study was to examine parents' perspectives about the online learning during the closures in Israel. We took a group of parents of TD and MD children. Both groups of parents reported that their child had a harder time being part of the virtual class compared to a regular class, and both groups reported that it was not so hard to find the right symbols on the keyboard during class.

However, in line with our expectations, the parents of the MD group reported that 1. the children needed more help from others to perform the online tasks. 2. They had a harder time in concentrating during online math class. 3. Last, they reported that the Corona time resulted in larger learning gaps in the MD compared to the TD.

An additional question of Experiment 1 was whether parents' perspectives about the child's weaknesses is related to the child's performances on mathematical abilities or to general cognitive mechanisms, at the basis of mathematical abilities. The results indicated that subjective parents' report of weakness in the survey was positively related to the child's actual weakness in complex multiplication and division tested by the key math III standardized task, and to individual weakness in verbal working memory.

In a recent study (Ashkenazi et al., submitted), we looked at the long term and short-term effects of Corona lockdown on retrieval of arithmetical facts in the same age group as in the present study. We looked at the short-term effect by examining addition fact knowledge, which was learned shortly before the lockdown, and multiplication facts that were learned after the Corona lockdown. As expected, in addition facts, participants that experienced the Corona lockdown, showed reduced performances compared to participants before the Corona lockdown. However, in multiplication facts, typically developing children post Corona lockdown showed better performances than children before the Corona. Children with mathematical learning disabilities showed weakness both in addition and multiplication with more severe deficits in

multiplication. While TD children improved in multiplication compared to Pre corona, for MD children, this was their biggest gap. The present result in addition to previous results indicating that multiplication facts are very sensitive to the effect of the Corona time. Additionally, we discovered here that verbal working memory of individual abilities was the only domain general factor associated with reported weakness. Verbal working memory is one of the building blocks of complex multiplication and division [30-33] . For example, [33] discovered that verbal working memory (digits backward), was a significant predictor of mathematical abilities at the beginning of elementary school. In a meta-analysis [34] found that a complex mathematical task has the strongest correlation with working memory. In a recent study, [35] examined the associations between multiple mathematical tasks including complex calculation and working memory tasks in children. They discovered that verbal working memory, but not visuospatial working memory, had a unique contribution to complex subtraction, multi-step computation and number series. Hence, it came as no surprise that the perceived difficulties of the child during the Corona period were associated with both complex calculations and verbal working memory deficits.

3. Experiment 2

Experiment 1 examined parents' perspectives about the short-term effect of the pandemic closures on elementary school children with or without learning disabilities. Experiment 2 was aimed at testing the long-term effect of the Corona period on classrooms of teachers with children with learning disabilities. Most of the previous studies have indicated that the Corona period resulted in significant learning lost to different degrees (Zierer, 2021). Please note, however, that these studies mostly examined the short-term effect of the closures. Indeed, a recent study tested the effect of the closures on addition and multiplication knowledge. We discovered learning lost in addition, that was learned during the Corona period. Interestingly, this was not the case for multiplication, that has been learned and trained post Corona. Hence, we found learning gain for subject matter that was learned after the Corona. In line with this view, we hypothesized that improved instructional methods of teachers after the Corona were the origin of these learning gains, due to an increase in the usage of digital aids. Hence, Experiment 2 was aimed at comparing teachers' usage of digital aids pre- and post- Corona.

3.1. Materials and Methods of experiment 2

3.1.1 Participants

We asked elementary 3rd or 4th grade school teachers, whose students were part of Experiment 1, from regular classes in the Northern District, to participate in Experiment 2. All the

teachers that were selected, started teaching before the Corona and currently continue to teach.

Fifteen females teachers answered the survey online, from 7 schools. Their ages ranged between 28- 57, average age = 42.33, S.D. = 7.09, their average time practicing teaching math is 13.4 years, SD = 8.58. One of the teachers was excluded due to missing data.

3.1.2 Tools

Teacher's digital aids questionnaire. All the items were answered twice, once referring to 2018 (prior to the Corona) and once referring to 2022 or 2023 (2 years after the Corona), for a total of 5 items X 2 =10. The first item asked about incorporating digital media during class. The second item asked about incorporating digital media during individual work in class. The third item asked about incorporating digital media during homework. The fourth item asked about training addition using digital aids. The fifth item asked about training multiplication with digital aids.

The survey was sent online and the general instructions for the teachers were "The next survey is designated for teachers of mathematics that were teaching in the Northern District during 2018 and during 2022 and 2023. The survey will refer to before and after the Corona period, and will try to discern a pattern of usage of digital aids before and after the Corona. Examples for digital aids could be websites that were acquired by the Ministry of Education such as "10 fingers". The scores were between 1- not at all, to 5 - very much.

3.2. Results of experiment 2

3.2.1 Response for the Teachers

A two-way repeated measures ANOVA was conducted on the responses with time (before, after) and item number (5) as the within-participants factors as the between-participants factor. The effect of time was significant $F(1,13) = 9.02$, partial $\mu^2 = .41$, $p = .01$. The effect of question was also significant $F(4,52) = 8.42$, partial $\mu^2 = .39$, $p = .001$. The interaction between time and question was not significant. The results are summarized in Table 3; as can be seen in Table 3, the use of digital aids was much more common after the Corona period (mean = 3.86, S.D. = 0.89) compared to before the Corona period (mean = 3.01, S.D. = 1.29).

3.3 Discussion of experiment 2

The main aim of the second study was to examine teachers' perspectives about the long-term effects of online learning during the closures in Israel. We took a group of teachers of MD and TD children at regular schools. Generally, teachers reported that they were using more digital aids post Corona as compared

to prior to the Corona. The biggest differences between before and after the Corona, were not due to digital aids during class, since in both cases teachers reported that they had used digital aids during class pre- and post- Corona. However, the biggest differences were in independent work during class (before mean = 3.93, after mean = 2.93) and as homework (before mean = 3.71, after mean = 2.71). Moreover, a similar increase was found in the instruction of addition and multiplication.

In a recent study, for the same population in multiplication facts, typically developing children post Corona lockdown showed better performance than children before the Corona. Hence, this improvement can be partially explained by the increase in digital aids as independent-work in class and outside class. A study conducted in the US examined the use of digital devices at home to support learning before and after the COVID-19 pandemic. The study found that children's reported use of digital devices and parents' confidence in assisting their children's learning with such devices increased from pre-COVID to post-COVID. confidence assisting their children's learning with such devices reportedly increased from pre- to post-COVID [36].

4. General discussion

The main goal of the present study was to test the perspectives of parents and teachers regarding students with mathematical learning disabilities, to the short and long-term effects of coronavirus closure. Many novel aspects can be found in the current study. First, we looked at a population of students with MD according to teacher assessments and curriculum-based tests. Second, we correlated parents' perspective with the actual performances of the child in mathematical tasks as well as cognitive factors. Third, we used children in the 1st and 2nd grades during the closures. These children were in their initial stages of acquiring basic mathematical abilities.

In a meta-analysis Zierer [10] found that most of the studies reported a learning gap to various degrees, although the size of the effect changed dramatically between studies, due to individual characteristics of the learner or Socioeconomic status. For example, learning gap was very severe for students from less-educated households, they experienced a greater loss of 60% compared to the general population [37]. Similarly, studies from all over the world found that learning gap was greater for students with learning disabilities compared to the general population [14]. In line with the investigator's view about learning gap, in children, especially children with learning disabilities, most of the parents, with a small preference for the parents of MD children, believe that the coronavirus closure had a negative effect on the learning of their child. Specifically, 75.8% of the parents of children from the MD group and 55.1% of the parents of children from the TD group

strongly agree with the item" The Corona period resulted in significant learning gaps among the students ".

Effective online learning requires physical conditions such as 1) a stable internet connection, 2) an available computer, and 3) a quiet environment [38]. The Program for International Student Assessment (PISA) s an international assessment that measures 15-year-old students' reading, mathematics, and science literacy [38]. The Pisa (2018) compared these physical conditions during online learning in the coronavirus closures across countries. According to the report, the Israeli learners had relatively good physical conditions during the coronavirus closure. Specifically, 1) According to the Pisa 2018, 90% of the students in disadvantaged schools, and over 95% of the students in advantaged schools reported that they had a quiet place to study. In our sample, only 50% of the TD and 42.5% of the MD parents reported that their child always had a quiet and isolated environment during online learning. 2) According to Pisa 2018, 90% of the students in disadvantaged schools and over 95% of the students in advantaged schools reported that they had an internet connection. In our sample, only 74% of the TD and 69.6% of the MD parents reported that their child had a stable connection to the internet during online classes. 3) According to Pisa 2018, 90% of the students in disadvantaged schools and over 98% of the students in advantaged schools reported that they had access to a computer for schoolwork. In our sample, only 70% of the TD and 72.8% of the MD parents reported that their child always had a computer available for learning. These findings demonstrated that students in the MD and TD groups had similar and good environments and materials for online learning. However, our results constantly demonstrated worse physical conditions in our sample compared to the results of Pisa 2018. Please note that our sample was much younger than the Pisa 2018 which included only 15-year-old students [38].

One of the main aims of the present study was to look at the different experiences of children with or without learning disabilities in online and remote learning during the coronavirus closure. One of the differences was related to the independency of the learner. Our two groups were children who were in the 1st or 2nd grades during the coronavirus closure, and accordingly, had minimal technical knowledge, and required extensive help from families. However, in line with previous studies, 72% of the parents of children from the MD group and only 37% of the parents of children from the TD group strongly agreed (give answer of 4 or 5) with the item "The student had a hard time performing the online task by his/herself and without help from others". Schuck and Lambert [14] have already reported that the online learning of students with learning disabilities requires great parental involvement, which might be a challenge to some of the parents. Moreover, in line with the greater general difficulties of MD students with mathematical learning in class or remotely, we discovered that

MD children had a harder time keeping track or concentrating during virtual class than TD children.

An additional goal of the present study was to look at the long-term effect of the coronavirus closure on learning environments. So far, most previous studies have examined the short-term effect of the corona virus closure. However, in a previous study with the same population (elementary school students who were in their 1st or 2nd grade during the corona virus closure and were tested two years later) for typically developing students, no long-lasting negative effects were found for learning multiplication facts, which were mostly learned post corona closure. This finding demonstrated that the coronavirus closure, in the long term, could result in learning gains. We hypothesized that the increase in the usage of digital aids, post-coronavirus closure, could be the origin of learning gains. From teachers' perspectives, they were unprepared for the sudden move to online learning during the coronavirus lockdown period [4, 23, 39, 40]. For example, in the report of the Pisa 2018 according to school principals, only 50% of the teachers in disadvantaged schools and 70% of the advantaged schools' teachers had the necessary technical and pedagogical skills to integrate digital devices into instruction. Moreover, only 50% of the principals in disadvantaged schools and 70% of the advantaged schools reported that teachers had sufficient time to prepare lessons integrating digital devices [38]. This demonstrates that during the closure, online learning was not satisfactory in Israel, especially for students in disadvantaged schools, and one can reasonably assume that applied to classes for students with learning disabilities. However, these unsatisfactory experiences with online learning during the initial closures might have improved teachers' technical and pedagogical skills to integrate digital devices into online learning, and as a result, improved the learning experience later on. In line with this view, we found that two years after the Corona closure, teachers incorporated many more digital aids in and outside of class. This can have particular importance to students with learning disabilities. The ability to practice mathematical or numerical abilities, by yourself and based on your individual abilities, can improve the learning process of students with learning disabilities [41]. Hence, incorporating digital aids, such as computer training, was found to be beneficial for students with mathematical learning disabilities [42, 43].

5. Conclusions

The main aim of the present study was to test the perspectives of parents and teachers about the short and long-term effects of the coronavirus closures on the learning process of mathematics, in children with mathematical learning disabilities. We used a population of students who were in the 1st and 2nd grades during the closures and tested them and their surroundings two years later. Children with MD had

physical conditions similar to the TD group, the two groups had a stable connection to the internet, a computer, and a quiet environment. However, MD children 1) needed more help and 2) had a harder time concentrating during virtual math class compared to TD children. Moreover, the coronavirus closures resulted in a greater learning gap in the MD children compared to the TD children. We found positive associations between difficulties reported by the parents and real weakness in performances in complex multiplication and division and verbal working memory.

We discovered that teachers are using digital aids much more today than before the coronavirus closure. We hypothesized that it results from the long lasting effect of the coronavirus closure. Incorporating digital aids in the learning experience has a potential beneficial effect on students with or without mathematical learning disabilities.

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Table 2

Table 2

Results from the factor analysis after relatability analysis

	Factor 1 loading (52.61%)
Q3	.80
Q8	.80
Q5	.73
Q6	.72
Q14	.67
Q1	-.66

Table 5

Correlations between average scores in questions that show group differences and numerical and mathematical abilities

Test	Correlation	Sig
Numerical Fluency (number of correctly solved addition and multiplication in 2 minutes)	-.17	.17
Simple operation (accuracy)	-.29	.02*
Comparison symbolic (RT)	-.10	.44
Comparison Non-symbolic (RT)	.10	.43
KeyMath Addition and subtraction (number of correctly solved)	-.26	.04*
KeyMath Multiplication and division (number of correctly solved)	**-.35**	**.004****
KeyMath Estimation (number of correctly solved)	-.29	.02*
KeyMath Numeration (number of correctly solved)	-.29	.02*

Note. * p< .05, ** p<.01 *** p < .001, bold font represents significance after Bonferoni correction (p < .006).

Table 6 *Teacher's responses to questions before and after the Corona.*

	The translated question	Before		After	
		Mean	*SD*	*Mean*	*SD*
1	Digital aids during class	3.86	0.86	4.29	0.83
2	Independent-work with digital aids during class	2.93	1.44	3.93	1.07
3	Homework with digital aids	2.71	1.38	3.71	1.14
4	Digital aids for training addition	2.71	1.35	3.64	1.08
5	Digital aids for training multiplication	2.86	1.41	3.71	1.07

* p< .05, ** p<.01 *** p < .001, bold font represents significance after Bonferoni

Does Grade Matter? Long-Term Effect of the Corona Closure on Mathematical Knowledge - The Case of Young Children with Mathematical Learning Disabilities

Abstract

Over recent years, many studies have explored effects of the Corona closures on learning mathematics and discovered that it resulted, mostly, in learning loss. However, studies investigating the long-term effects of closures on testing specific mathematical subject matter are lacking. We investigated the closure effects on the ability to master subject matter learned remotely during the closure. Two groups of typically developing children (TD, N= 105) and children with mathematical learning disabilities (MD, N= 79) were tested 2 years post-Corona.

TD children were able to fill the gaps in most of the subject matter learned during the Corona closure. However, for students with MD, learning losses were more severe and were related to their school grade during the lockdown. While MD in the 1st grade during the lockdown showed weakness in specific subject matters (e.g., simple and complex subtraction). MD who were in the 2nd grade during the lockdown, displayed a complete lack of understanding in calculations, equations, and place values, in addition to large discrepancies in most of the other subject matter. Lack of understanding place values blocked the capacity of MD students to learn other subject matter from the 2nd grade on.

Keywords: Corona closure, developmental dyscalculia, mathematical learning disability, mathematics, individual differences, mathematical curriculum.

Poor numerical and mathematical understanding is associated with negative outcomes in daily life and in the academic world. For example, poor numerical and mathematical understanding is connected to higher rates of employment in low-paying manual occupations and more frequent periods of unemployment. Poor numerical and mathematical understanding can result from developmental disabilities, inadequate schooling, and any combination of these factors (An et al., 2021; Parsons & Bynner, 1997).

Developmental dyscalculia (DD) or mathematical learning disability (MD) is defined as a "specific disorder of arithmetical skills that is associated with a specific brain dysfunction" (Ashkenazi, Black, et al., 2013; Ashkenazi, Mark-Zigdon, et al., 2013; Ashkenazi et al., 2012; Henik et al., 2011; Kosc, 1974; Shalev et al., 1993). It has been suggested that humans and primates are born with intuitive and preverbal number sense (Dehaene, 1992; Dehaene et al., 2003). Number sense is the inborn ability to represent and compare approximate non-symbolic quantities (Dehaene, 1992; Dehaene et al., 2003). Later, with development and practice, a culturally and verbally mediated exact number system is developed (Halberda & Feigenson, 2008; Halberda et al., 2008; Libertus et al., 2011; Mazzocco et al., 2011). There is a disagreement whether MD originates from the innate preverbal representation of quantity (Halberda & Feigenson, 2008; Halberda et al., 2008; Libertus et al., 2011; Mazzocco et al., 2011) or the verbally mediated exact numerical system. According to the number sense theory (De Smedt et al., 2013; Noel & Rousselle, 2011) MD is based on weakness in innate number sense resulting in exact number representation that develops later on, and weakness in multiple numerical and mathematical domains. However, the alternative theory suggests that the innate number sense and the culturally and verbally mediated exact number system are largely dissociable, and MD results from weakness in the exact verbally mediated number system based on weakness in the innate representation of small quantities, with intact number sense (De Smedt et al., 2013; Noel & Rousselle, 2011). To understand the core deficits in MD, most of the studies regarding MD have focused largely on magnitude or number representations or arithmeticseeking for the main deficits in these domains (Geary, 1990, 2004; Geary et al., 1991; Jordan & Montani, 1997; Russell & Ginsburg, 1984) . According to the number sense theory, the core weakness in MD is the innate preverbal representation of non-symbolic and symbolic quantities. Hence, this line of studies focused on a comparison of numbers and translation between symbolic and non-symbolic representations. Indeed, a recent meta-analysis suggested that deficits in comparison are one of the main characteristics of MD (Castaldi et al., 2020; Espina et al., 2023; Mishra & Khan, 2023). Additional discrepancies were also found in calculations. A frequently reported deficit in MD relates to the retrieval of arithmetical facts. MD participants use calculation backup strategies when solving simple calculations (such as 3 X 4 or 4 +5), while their peers are use mostly memory-based strategies. Additionally, MD children have deficits in procedural

knowledge and the proper usage of procedures in complex calculations (Geary, 2004; Geary et al., 2007; Ostad, 1997).

In most of the studies, the classification of MD involves the use of a standardized mathematical test with a specific cutoff point for inclusion in the MD group (ranging from approximately the lowest 3 – 25%). Moreover, the classification of MD usually comprises exclusion criteria of impairment in arithmetical skills that is not explicable based on inadequate schooling (e.g., DSM 4) (Nelson et al., 2022).

However, please note that approximately three years ago, the entire world experienced inadequate schooling during the coronavirus lockdowns, and schools switched suddenly without correct preparation, to online learning. Schools were closed during the lockdown in the Spring of 2020 in almost every country in the world. In Israel, specifically, the education system was closed from 2020 to 2021 between 11.5 to 24 weeks (Buonsenso et al., 2021).

Most of the studies that tested effects of the corona closure on learning mathematics found that the corona period resulted in varied degrees of learning loss (Zierer, 2021). For example, Kuhfeld et al. (2022) compared mathematical performances before and after the closures in the USA and found that both 3rd and 4th-grade children's mathematical performances decreased by 9 percentile points after the closures, as compared to before the closures. Maldonado and De Witte (2022) looked at the effect of 7-week closures in Belgium and found a 0.19 standard deviation decrease in the test values achieved in mathematics. One of the explanations for this great heterogeneity in the effect of closures is individual differences, such as the presence of learning disabilities (Kadarisma & Juandi, 2021; Petretto et al., 2021; Poletti, 2020).

Participants with learning disabilities are more likely to be heavily affected by the closures than their typically developing peers (Schuck & Lambert, 2020). Specifically, children with MD need more help from others during online learning, which might be a challenge to their families. Moreover, for children with MD who need the the school's support network more than others, the school support network is absent in online distance learning (Schuck & Lambert, 2020).

Poor mathematical understanding can be associated both with MD or inadequate schooling. It is hard to determine, based only on a cutoff point in the standardized test created pre-Corona, who should be classified as MD post-Corona. Moreover, it is not clear how the individual characteristics of the learner, such as learning disability and the class that he/she attended during the lockdown, shaped the knowledge of the child in the post-Corona world.

The present study

It has been documented that in most countries, the effect of the coronavirus pandemic has led to significant universal learning loss. The present study proposes to explore learning loss two years post-Corona in a group of students with MD or typically developing (TD) students during their 1st or 2nd grade during the coronavirus lockdown.

Children who were in the 1st and 2nd grades during the closures are a unique population because 1) they were in their initial stages of learning arithmetic, which are the initial building blocks

of arithmetical knowledge later on. 2) Children in the 1st and 2nd grades are too young to fully participate in remote learning independently without the help of others, and for a full grade. Moreover, mathematics at the beginning of elementary school is a very hard topic for online learning, since it requires multiple physical demonstrations, that cannot easily be performed remotely.

We selected a group of TD and a group of children with MD. The MD group was defined due to 1) severe difficulties in mathematics according to their teachers, and 2) according to their score on a standardized test: the lowest 13% in curriculum-based tests that were designed by the Ministry of Education in Israel. We selected children that were in the 1st or 2nd grades during the closures, and tested those children 2 years later during their 3rd or 4th grades. We looked at multiple subject matters that had been learned during the coronavirus lockdown according to the mathematical curriculum in Israel. Specifically, we created a test with all the subject matter that according to the Israeli mathematical curriculum, ought to be learned in the 1st or 2nd grades. We administered the test of the 1st-grade curriculum to children who were tested in the 3rd grade, and the test of the 2nd-grade curriculum to childrenwho were tested in the 4th grade. A small group of children, who were in the 1st grade during the Corona lockdown and learned the 2nd grade curriculum one-year post-Corona, alsocompleted the 2nd grade curriculum test, to look at the long-term Corona effect.

We hypothesized that two years after the coronavirus lockdown, TD children would be able to fill the gap in most subject matter learned during the lockdown, and would show high accuracy on most of the subject matter learned during the 1st and 2nd grades.

As mentioned above, MD participants show multiple deficits in numerical representation and arithmetic (Agostini et al., 2022; De Smedt et al., 2013; Espina et al., 2023; Geary, 1990, 2004, 2011; Jordan & Montani, 1997; Mishra & Khan, 2023; Russell & Ginsburg, 1984). Hence, we hypothesized that MD children would show weakness in multiple subject areas, regardless of the Corona lockdown, such as numerical comparison, solution of arithmetical fact, subtraction, and estimation (Dehaene, 1992; Dehaene et al., 2003; Dehaene et al., 1999; Mazzocco et al., 2011). Moreover, we hypothesized that MD children would show greater learning loss than TD children, and we believed the learning gap would be modulated by school grade during the Corona lockdown.

Materials and Methods

Defending the MD group

In the first step, we asked elementary school teachers from regular classes in the Northern District of Israel to select a group of children from the 3rd or 4th grades according to 1) Teacher assessment that they suffer from severe difficulties in mathematics. 2) According to achievements in mathematical curriculum-based tests in Israel (lowest 13%). The mathematical curriculum-based test was administered to all children in Israel during these

years. Children who met these two criteria were defined as the mathematical difficulties (MD) group. We also asked the same elementary school teachers to provide us with an additional group of children with average or above-average math performances. This group was defined as 'typically developing' (TD).

One hundred and sixty children were selected from the 3rd and 4th grades, from 7 schools in the Northern District in Israel. Fifty-three of them were from the 3rd grade and completed the 1st grade test, 48 were in the TD group, of which 30 were females (mean age = 8.69, S.D. =0.58) and 31 were from the MD group grade, 17 were females (mean age = 8.72, S.D. =0.58). There were no significant age differences between the groups, $t(73) = -.21$, $p = .83$. Thirty-five of them were from the 3rd grade and completed the 2st grade test, 24 were in the TD group, of which 12 were females (mean age = 8.63, S.D. =0.54), and 11 from the MD group grade, of which 9 were females (mean age = 8.74, S.D. =0.45). There were no significant age differences between the groups, $t(33) = -.55$, $p = .58$. One hundred and seven of them were from the 4th grade and completed the 2st grade test, 54 were in the TD group, of which 23 were females (mean age = 9.88, S.D. =0.42) and 53 from the MD group grade, 41 of whom were females (mean age = 9.9, S.D. =0.42). There were no significant age differences between the groups $t(101) = -.42$, $p = .67$.

The parents of all the participants signed a consent form for participation in the experiment. The study was approved both by the ethics committee of the Education Ministry and the School of Education at the Hebrew University. Two of the MD group participants did not complete all the tests and were excluded. One of the participants in the MD group quit during the experiment due to difficulties.

Defending the DD group

In the second step each of the participants defined as MD, completed 4 subtests from the KeyMath III diagnostic test, including numeration, estimation, written calculation addition and subtraction, written calculation multiplication, and division. We calculated the average standardized by-age score of the Key Math to classify participants. Every participant with a standardized score of less than -1.2 SD equal to the lowest 12% of performances was entered

into the developmental dyscalculia group (DD). We found a subgroup of 8 children that met the criteria of DD from the 3rd grade, mean age = 8.75, S.D.= .35 50% of them were females, and 35 from the 4th grade mean age = 10.03, S.D.= .34 87% of them where females.

Key Math III test

This was used only for the cohort of 2022- 2023. Mathematical abilities were assessed using KeyMath subtests: numeration, mental computation and estimation, addition and subtraction, and multiplication and division (Connolly, 1998). We chose KeyMath due to its comprehensive inclusion of several mathematics subtests, and our laboratory had translated it into Hebrew for previous studies (Silverman & Ashkenazi, 2022). In addition, since it is a standardized measure, it has high reliability (median subtest-retest reliability .88; (Connolly, 1998). The reliability between the subscales for the participants in the current study was very high (Cronbach's alpha = .90). The items of each subtest are arranged in order of difficulty. The experimenter moves on to the next subscale after four consecutive errors or the end of the subscale. Numeration, mental computation, and estimation were conducted orally, with each item presented on the KeyMath easel, while addition and subtraction and multiplication and division were paper and pencil tests.

The numeration subtest includes 49 questions related to numerical understanding (place value, magnitude, number sense, decimals, fractions, percentages, exponents, integers, multiples, and factors). Mental computation and estimation, addition and subtraction, and multiplication and division are all part of the KeyMath area operations. Mental computation includes 40 items related to mental computation of whole and rational numbers, mental computation chains, and estimation of whole and rational numbers. Addition and subtraction included 35 items, and multiplication and division included 31 items. Both subtests ranged from basic operations with integers to algebra. All of the KeyMath subtests were given a raw score, the number of correct answers in addition to a standardized score according to grade level. The KeyMath average score was used to classify participants into their developmental dyscalculia group.

Curriculum-based tests check the subject matter required in the first grade.

The first-grade mathematical curriculum includes understanding of natural numbers until 20, parity and number line, counting, and numerical comparison. Addition and subtraction until 10. All of these subject matters were evaluated in our tests. Please see Table 1 for all the subject matters and examples. Every row in Table 3 had 3 repetitions, but some comparisons had 4 repetitions.

Curriculum-based tests test the subject matters required in the 2nd grade.

The second-grade mathematical curriculum includes the understanding of natural numbers until 100, with a spatial emphasis on place value, parity and number line, counting, and numerical comparison. Addition and subtraction until 100 and simple multiplication and multiplication rules. All of these subject matters were tested in our tests. Please see Table 1 for all the subject matter and examples. Every row in Table 3 had 3 repetitions, but some comparisons had 4 repetitions.

Results

Group Comparison of Responses for subject matter of the 1st grade for students in the 3rd grade. In the current analysis, we included the TD group, which according to their teachers had average school achievements, and the MD group which according to their teachers and curriculum-based measurements had severe difficulties in arithmetic from the 3rd grade. We examined the student knowledge in multiple subject matters that are part of the curriculum in the 1st grade, that was learned during the closures.

Accuracy analysis.

A two-way repeated measures ANOVA was conducted on the response with subject matter (1-11 for all the topics, see Table 1) as the within-participants factor and group (MD or TD) as the between-participants factor. The effect of the subject matter was significant $F(1,72) = 25.52$, partial $\mu^2 = .26$, $p = .0001$. The interaction between group and subject matter was also significant $F(1,72) = 17.96$, partial $\mu^2 = .20$, $p = .0001$. Accordingly, we tested group differences in each subject matter. The results are summarized in Table 2 and in Figure 1. First, TD participants ($M = .99$, $S.D. = .068$) were more accurate than MD participants ($M = .89$, $S.D. =$

.18), in addition (for example 4 + 3 = ?), in medium effect size, t (76) = 3.23, p = .002. Second, TD participants (M = .92, S.D. = .22) were more accurate than MD participants (M = .80, S.D. = .25) in indicating which number is between two numbers (for example, what number is between 8 to 15? 6, 9, 16 or 4), in medium effect size, t (76) = 2.23, p = .029. Third, TD participants (M = .94, S.D. = .15) were more accurate than MD participants (M = .83, S.D. = .19) in enumeration (for example, participant counted 12 shapes), in medium effect size, t (76) = 2.24, p = .020. Fourth, TD participants (M = .97, S.D. = .14) were more accurate than MD participants (M = .77, S.D. = .37) in parity (for example, please select the even number: 1, 9, 8, 5), in large effect size, t (76) = 2.24, p = .020. Fifth, TD participants (M = .97, S.D. = .14) were more accurate than MD participants (M = .77, S.D. = .37) in series (for example, please complete the following series __, 4, 6, 8). Last, TD participants (M = .97, S.D. = .14) were more accurate than MD participants (M = .77, S.D. = .37) in subtraction (for example, 18 -7 = ?).

Since TD children learned this subject matter 2 years ago, they should have perfect performances in this subject matter. Accordingly, we examined whether the scores of the TD are significantly lower than 95%. Only 1 subject matter was significantly lower than 0.95- number line estimation (Mean TD = 0.87, SD = 0.22), t (46) = -2.48, p = .017.

Reaction time (RT) analysis.

Only 3 subject matters showed very high accuracy rates (accuracy rate > 0.93) in the two groups, enabling RT analysis. A t-test for independent groups (MD or TD) was conducted on the RTs of the correct trials. The results indicated that the RT of the two groups in comparisons was similar (TD = 2716, SD = 1896; MD = 2889, SD = 1269), t (78)= -.45, p = .67. Similarly, the RT of the two groups in counting was similar (TD = 10726, SD = 3940; MD = 11273, SD = 5370), t (72)= -.51, p = .61. However, MD were slower to respond than TD on exact number line (TD = 4083, SD = 1296; MD = 5269, S.D. = 1862), t (48)= -3.09, p = .003.

Group Comparison of Responses for 2nd grade subject matter for students in the fourth grade.

In the current analysis, we included the TD group, which according to their teacher had average school achievements, and the MD group which according to their teachers and curriculum-based measurements had severe difficulties in arithmetic from the 4rd grade. We examined student knowledge in multiple subject matters that are part of the 2nd grade curriculum that was learned during the closures.

A two-way repeated measures ANOVA was conducted on the response with subject matter (1-16) as the within-participants factor and group (MD or TD) as the between-participants factor. The effect of subject matter was significant, $F(15,1575) = 30.87$, partial $\mu^2 = .23$, $p = .0001$. The interaction between the group and the subject matter was also significant, $F(15,1575) = 17.01$, partial $\mu^2 = .14$, $p = .0001$. Accordingly, we tested group differences in each subject matter. The results are summarized in Table 3. In most of the subject matters, but not comparisons, TD children were more accurate then MD (effect size range 0.87 - 2.06). Specifically in: addition, changing unit decade, create the biggest or smallest number, estimation, find number equations, multiplication, number line exact, parity, complex and subtraction. However, in reading numbers (effect size = 0.72) and number line estimation (effect size = 0.52) TD children were more accurate than MD in medium effect size. Comparison was the only subject matter in which MD were more accurate than TD (TD = 0.92, SD = 0.14; MD = 0.98, SD = 0.08) ($p = 0.05$).

Since TD children learned these subject matters 2 years before the date of testing, they should have had perfect performances in these subject matters. Accordingly, we examined whether the scores of the TD are significantly lower than 0.95. Only 2 subject matters were significantly lower than 0.95: 1) changing units decade TD = 0.87, SD = 0.28, $t(54) = -3.4$, $p = .001$, and 2) subtraction - TD = 0.76, SD = .32, $t(54) = -5.45$, $p = .001$.

RT analysis. Due to the high accuracy rates in the two groups, we were able to compare reaction times between groups. The results indicated that the RT of the two groups in comparisons was similar (TD = 3791, SD = 2681; MD = 4661, SD = 5969), $t(107) = -.91$, $p = .372$.

Group Comparison between MD and DD of Responses for 2nd grade subject matter, for students' accuracy in the 4th grade.

In the current analysis, we included children from the MD groups only in arithmetic and participants from the DD (MD n = 23) group which according to the standardized key math III test had severe difficulties in arithmetic from the 4th grade during testing. We examined student knowledge in multiple subject matters that are part of the 2nd grade curriculum and were learned during the closures.

A two-way repeated measures ANOVA was conducted on the response with subject matter (1-16) as the within-participants factor and group (MD or DD) as the between-participants factor. The effect of subject matter was significant, $F(15,765) = 28.09$, partial $\mu^2 = .36$, $p = .0001$. The interaction between group and subject matter was not significant, $F(15,765) = 0.70$, partial $\mu^2 = .01$, $p = .80$. The effect of group was not significant as well, $F(1,51) = 0.58$, partial $\mu^2 = .006$, $p = .58$. The results are summarized in Table 4. We could not carry out the same analysis with the 3rd graders due to power issues (only 8 of the MD children were defined as DD).

Group Comparison of Responses for 2nd grade subject matter for accuracy of students in the 3rd and the 4th grades.

In the current analysis, we included TD and MD children who were in the 3rd or 4th grade during testing, and tested them on 2nd grade subject matter. The 4th grade children had learned these subjects during the closure, and for the 3rd grade children, these subject matters were learned one year after the closure.

A three-way repeated measures ANOVA was conducted on the responses with subject matter (1- 16) as the within-participants factor and group (MD or TD) and current grade (3 or 4) as the between-participants factor. The effect of subject matter was significant $F(15,1995) = 21.75$, partial $\mu^2 = .14$, $p = .0001$. The interaction between group and subject matter was also significant, $F(15,1575) = 12.31$, partial $\mu^2 = .085$, $p = .0001$. The interaction between subject and grade was not significant ($p = .07$) and the interaction between group, grade and subject matter was not significant ($p = .18$). However, the main effect of class was significant, F(1,133)

= 6.0, partial μ^2 = .043, p =.016. Children in the 3rd grade were more accurate than children in the 4th grade (3rd = 0.89, SD = 0.21, 4th = 0.77, SD = 0.35). There were a main effects of group, F(1,133) = 42.17, partial μ^2 = .24, p =.001, and TD children were more accurate than MD children (TD = 0.95, SD = 0.12, MD = 0.62, SD = 0.37). Last, the interaction between grade and group was significant, F(1,133) = 5.12, partial μ^2 = .037, p =.025. In order to understand the interaction, we split our analysis by group. In the TD group there were no significant effect of grade (p = 0.58), or interaction between grade and subject (p = 0.67). However, in the MD group, there was a main effect of grade F(1,62) = 4.44, partial μ^2 = .067, p =.039. The MD children in the 3rd grade were more accurate than MD children in the 4th grade (3rd = 0.78, SD = 0.26, 4th = 0.58, SD = 0.38) (Please see Figure 2).

Discussion

The current study examined the long term effects of the coronavirus lockdown on children who were in the initial stages of learning mathematics during the lockdown. We examined all the subject matter in the Israeli curriculum which were learned during the lockdown in the 1st grade for children who were tested in the 3rd grade, or all the subject matter in the Israeli curriculum learned during the lockdown in the 2nd grade for children that were tested in the 4th grade. Most previous studies that examined learning loss in mathematics examined the average learning lost without looking at the specific learning lost in each subject matter and reported learning lost to differentiate degrees (Zierer, 2021). However, the long-term effect of the corona closure on specific subject matters were rarely examined. Hence, the main goal of the present study was to test the differential influence of the lockdown on students with or without mathematical learning disabilities.

TD children, who were in the 1st or 2nd grades during the lockdown, and were tested two years post Corona, were able to fill the gaps in most subject matters that were learned during the Corona closure. Mild learning loss was observed in number line estimation (accuracy = 87% S.D.= 22%) for students who were in the 1st grade. Number line estimation, in contrast to exact number line, is not explicitly drilled in class. Students who were in the 2nd grade during the

Corona lockdown showed mild deficits in two-digit subtraction (accuracy = 75% S.D.= 33%) and place value (accuracy = 87% S.D.= 27%).

For students with MD learning loss was more severe and was related to their class during the lockdown. MD students who were in the 2nd grade showed greater learning loss than MD students who were in the 1st grade during the lockdown.

Specifically, students who were in the 1st grade during the lockdown showed minimal learning loss, based presumably on the typical weakness of MD students. These weaknesses included comparisons between numbers (Cohen's d = 0.51), enumeration (Cohen's d = 0.64), simple addition (Cohen's d = 0.66) and parity (Cohen's d = 0.71) in a medium effect size and more severe deficits in subtraction (Cohen's d = 0.86) and series (Cohen's d = 1.30) in a large effect size.

The preverbal representation of quantity is believed to be needed for estimation tasks (Halberda & Feigenson, 2008; Halberda et al., 2008; Libertus et al., 2011; Mazzocco et al., 2011). During numerical estimation, a quantity (symbolic or non-symbolic) is translated into an abstract code of that quantity in the form of the number line (Dehaene & Cohen, 1994; Dehaene et al., 2003). The mental number line is also required in subtraction more than in multiplication, and in complex unstructured numerical tasks or numerical comparisons (Dehaene & Cohen, 1994; Dehaene et al., 2003).

Subtraction, series, and number comparison weakness can be based upon a core deficit in the mental number line and quantity understanding, as observed in MD children (Dehaene et al., 2003; Kroesbergen et al., 2023; Mazzocco et al., 2011). However, weakness in parity and addition can reflect an additional flaw in the verbally mediated quantity code in MD (Dehaene et al., 2003). In line with deficits in addition, a recent meta-analysis discovered that MD children show deficits in multiple calculation domains, and that these deficits are similar between complex and simple calculations (Kroesbergen et al., 2023). Last, it has previously been reported that MD children show enumeration weakness from early childhood until adulthood (Ashkenazi, Mark-Zigdon, et al., 2013; Decarli et al., 2020). In line with this view, we found that MD children who were in the 1st grade during the lockdown showed medium weakness in enumeration.

The MD children who were in the 2nd grade during the lockdown showed severe deficits in most of the subject matters tested, except for two-digit comparisons. In fact, MD children who were in the 2nd grade showed accuracy below 55%; therefore, they displayed a complete lack of understanding, in all calculations including two-digit addition and subtraction and one-digit multiplication (but not multiplication rules) and in equation and place value. In all the rest of the subject matters that were tested, they showed a large effect size compared to TD, except for reading numbers and number line estimations that showed a medium effect size.

Previous studies had argued that a distinction should be made between different types of MLD, based on severity of mathematical deficits (Geary, 2011; Mazzocco et al., 2011). In line with this view, we divided our MD group into participants with severe deficits in a standardized test entitled DD, and the rest of the MD group that did not pass the criteria for DD. Previous studies indicated dissociations between the abilities of MD and DD, for example Mazzocco et al. (2011) that discovered that number sense deficits characterized DD but not MD. However, in our study the learning loss of students that were tested during the 4th grade, were similar to children who were defined as MD and DD. The latter suggests that learning loss was related more to the interactive effect of learning disabilities and the Corona closures than to severity of the learning disability. Hence, in line with Kroesbergen et al. (2023) we were not able to detect a consistent and specific profile of cognitive mechanisms underlying more serious, persistent, or specific difficulties of DD compared to MD.

One task that aimed at examining the number space association, is the number line estimation task (Booth & Siegler, 2006; Siegler, 2016; Siegler & Opfer, 2003). According to this task, MD children are expected to show severe weakness in number line estimation tasks (Geary et al., 2008). Please note that contrary to our expectations, MD children who experienced the Corona lockdown in the 1st grade showed intact number line representation in both exact number line and estimation. In number line estimation, TD children and MD children showed similarly minimal weakness. Similarly, MD children who experienced the Corona lockdown in the 2nd grade, showed a relatively small weakness in number line, thus indicating that number line representations are mostly intact amounts MD.

We also compared the long term effect of the corona closure on children who were tested during the 3rd grade and children who were tested in the 4th grade, on the 2nd grade curriculum (the 3rd grade children learned it in class one year post corona, while the 4rd grade children learned it remotely during the coronavirus closure). For TD children there were no effect of grade, both groups show near prefect performances. Importantly, we found that MD in the 3rd grade were more accurate than 4th grade MD's, indicating that MD children are able to better understand the subject matter learned during the 2nd grade if they are taught in class rather than remotely.

Accordingly, MD students who were in the 2nd grade during the Corona closures is the group that experienced the greater learning loss compared to all the other tested groups. They could not make up the Corona learning loss, even partially, in some of the subject matters. The main topic that is learned during the 2nd grade but not during the 1st grade is place value. We believe that the large gaps between MD children who were in the 1st grade or 2nd grade during the lockdown is partially based on the MD students' inability to understand the place value principle remotely. Accordingly, they were unable to fill the gap later, when returning to traditional in- class learning, and understand more complex mathematical principles later (Wittmann, 1994).

The place value is a notational system for representing written numerals In our Arabic digit system, positional property and base-10 rules dictate the meaning of multi -digit numbers (Cheung & Ansari, 2021). Understanding the place value principle requires the understanding of two independent components. First, position- the identity (as a unit or decade) of a specific digit in a multidigit number, is based on it's place in the multidigit number (Baroody, 1990). For example in 52, 5 is the decade and 2 is the unit. Second, bundling 10- exchange rates of 1:10 between different digits in two digit numbers. The first principle is easier to understand and is learned explicitly, whereas the second is harder to understand and is learned more implicitly by training with multidigit numbers (Baroody, 1987). Most of the previous studies did not separate these two components. Moreover Cheung and Ansari (2021) discovered that fully understanding the relationship between place and value in multidigit numbers takes years to master. However, it is not clear whether MD should show weakness in place value

understanding. A recent study that tested 4th graders with MD found that Place value understanding was the only subject matter that was similar between MD and TD (Andersson, 2008). This study mostly tested the position component of the place value, but not the bundling 10 component.

In our study in the 2nd grade curriculum test, creating the biggest or smallest number and number reading examined the first component of position and changing unit decade and multidigits calculation, especially subtraction, examining the second component of the place value principle bundling 10. Changing unit decade was one of the subjectsin which TD children show mild deficits (87% accuracy) and in which MD children show only a 35% accuracy. Indicating that understanding of exchange rates between digits in a two-digit number is a topic that is hard to learn remotely, either for TD and especially for MD children. Another indication for the deficits in understanding the component of exchange rates between digits in two-digit numbers is two-digit calculations, that reflect very severe deficits in MD and mild deficits specifically in subtraction in TD children.

However, the first component of place value- position was found to be fully understood in TD children and better understood in MD children. Specifically, TD children in the 4th grade showed near perfect performances in reading numbers and creating the largest or smallest number, while MD children showed only medium deficits in these topics (accuracy between 59% to 73%).

We believe that weakness in the understanding of the place value of MD can result in severe difficulties in all the other 2nd grade subject matters. One such example is parity. MD children from the 3rd grade have shown only minimal weakness in single digit parity (accuracy = 77%), however, MD children from the 4th grade have shown meaningful weakness in two-digit parity (accuracy = 48%). Two-digit parity requires understanding the parity principle, in addition to understanding the place value principle. Specifically, a child should understand what are unit digits and that the parity of just the unit digits determines the parity of the whole two-digit number.

Conclusion

The present study examined the long-term effect of the Corona closure, by testing, two years later, the understanding of the subject matters that were learned remotely. We looked at grade and the presence of mathematical learning disability as possible mediators for learning loss.

Students without learning disabilities were mostly able to fill the gaps in most of the subject matter, except for number line estimation in the 1st grade curriculum, which is not learned explicitly at school. In the 2nd grade curriculum, TD children show minimal learning loss in understanding the component of bundling 10 in place value, and as a result mild learning loss in multi digit subtraction.

The results were more heterogeneous in the group of children with mathematical learning disabilities, and were modulated by grade during the lockdown. MD children who were in the 1st grade during the lockdown showed relative understanding of all the subject matter learned during the Corona closure, with the typical weakness observed in MD children. In previous studies MD participants showed multiple deficits in numerical representation and arithmetic (Agostini et al., 2022; De Smedt et al., 2013; Espina et al., 2023; Geary, 1990, 2004, 2011; Jordan & Montani, 1997; Mishra & Khan, 2023; Russell & Ginsburg, 1984) In line with this broad view, our MD group showed severe weakness in subtraction and serious and medium deficits in number comparison, enumeration, simple addition and parity.

However, Learning gaps for MD students who were in the 2nd grade during the lockdown were much greater. MD children who were in the 2nd grade showed accuracy below 55%, and therefore displayed a complete lack of understanding, in all the calculations, equations and place value. In most of the other subject matters, they showed weakness with a large effect size.

The main differences in the curriculum of the 1st and 2nd grade is place value and understanding multidigit numbers. Understanding of the place value principle, and specifically the bundling 10 component, for MD in the 2nd grade was very hard in remote learning. We believe that lack of understanding of place value blocks the abilities of MD students to understand other subject matter learned during the 2nd grade. In the post corona world, it will be important to teach MD students explicitly in class, the place value subject matter.

Statements and Declarations

Competing Interests.

None.

Data transparency

All the data will be sent upon request from the first author.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by SA and SH. The first draft of the manuscript was written by AS and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript

Table 1. Examples for each subject matters in each class

	1st	*2nd*
Closer to number	What is closer to 7? 5 or 3	_____
Between numbers	What number is between 8 and 15? 6, 9, 16,4	_____
Count up	Count from 11 to 21	_____
Enumeration		_____
Changing unit decade	_____	If you will changed the decade digits in 52 to 4, in how much the number will change?
Create the biggest number	_____	Please create the largest number from 6 and 3
Create the smallest number	_____	Please create the smallest number from 2 and 0
Estimation	_____	Whether the results of 54 +36 is larger or smaller than 100?
Find a number	_____	Find a number that is greater by 2 than 24
Equations	_____	3 + ? = 26

Table 2.

Results of all the subject matter from the curriculum of grade 1 for students in grade 3.

	TD (n=43)		MD (n= 31)		
	Mean	*SD*	*Mean*	*SD*	*P*
	0.93	**0.17**	**0.72**	**0.29**	**.001****
Subtraction Series	**0.95**	**0.14**	**0.67**	**0.24**	**.001****
Parity	**0.97**	**0.14**	**0.77**	**0.39**	**.004****
Number line estimation	0.87	0.22	0.81	0.18	.168
Number line exact	0.98	0.07	0.95	0.15	.12
Enumeration	**0.94**	**0.15**	**0.83**	**0.19**	**.02***
Counting	0.99	0.07	0.96	0.19	.235
Comparison	0.94	0.16	0.93	0.17	.899
Closer to number	0.92	0.19	0.86	0.17	.087
Between numbers	**0.92**	**0.22**	**0.80**	**0.25**	**.029***
Addition	**0.98**	**0.07**	**0.89**	**0.18**	**.002****

* p< .05, ** p<.01 *** p < .001, bold font represents significant differences, an underline represents lower than 0.95 for the TD group.

Table 3

Results of all the subject matter from the curriculum of grade 2 for students in grade 4.

		TD (n=54)	MD (n= 53)			
	Mean	*SD*	*Mean*	*SD*	*P*	*Cohen's D*
	0.96	0.14	0.41	0.35	.001**	2.06
Addition Changing unit decade	0.87	0.27	0.32	0.35	.001**	1.75
Comparison	*0.92*	*0.22*	*0.98*	*0.08*	*.05*	*0.36*
Create the biggest number	0.98	0.14	0.59	0.45	.001**	1.17
Create the smallest number	0.94	0.22	0.62	0.46	.001**	0.88
Estimation	0.94	0.17	0.57	0.41	.001**	1.17
Find a number	0.96	0.15	0.59	0.41	.001**	1.19
Equations	0.95	0.17	0.40	0.40	.001**	1.78
Multiplication	0.95	0.19	0.45	0.40	.001**	1.59
Multiplication rules	0.99	0.22	0.69	0.43	.001**	0.87
Number line exact	0.97	0.14	0.69	0.43	.001**	0.87
Number line estimation	0.96	0.10	0.85	0.28	.009*	0.52
Parity	0.96	0.15	0.48	0.41	.001**	1.61
Read number	0.96	0.15	0.73	0.42	.001**	0.72
Serious	1	0	0.63	0.45	.001**	1.15
Subtraction	0.75	0.33	0.23	0.34	.001**	1.551

An underline represents lower than 0.95 for the TD group.

Table 4

Results of all the subject matter from the curriculum of grade 2 for students in grade 4.

		MD (n=30)		DD (n= 23)	
		Mean	*SD*	*Mean*	*SD*
	0.44		0.38	0.35	0.29
Addition Changing unit decade	0.38		0.37	0.25	0.31
Comparison	0.98		0.09	0.99	0.05
Create the biggest number	0.61		0.46	0.56	0.44
Create the smallest number	0.64		0.47	0.59	0.47
Estimation	0.60		0.41	0.54	0.41
Find a number	0.60		0.41	0.58	0.40
Equations	0.50		0.42	0.51	0.40
Multiplication	0.52		0.39	0.38	0.40
Multiplication rules	0.70		0.45	0.69	0.43
Number line exact	0.68		0.44	0.71	0.44
Number line estimation	0.86		0.29	0.85	0.30
Parity	0.53		0.42	0.44	0.39
Read number	0.71		0.42	0.77	0.42
Series	0.66		0.47	0.59	0.42
Subtraction	0.28		0.30	0.16	0.34

Table 4

Results of all the subject matter from the curriculum of grade 2 for students in grade 4 and 3 by group.

	TD 4th (n=54)		MD 4th (n= 53)		TD 3th (n=19)		MD 3th (n= 11)	
	Mean	SD	Mean	SD	Mean	SD	*Mean*	*SD*
Addition	0.96	0.14	0.41	0.35	0.98	0.02	0.63	0.11
Changing unit decade	0.87	0.27	0.32	0.35	0.96	0.02	0.42	0.14
Comparison	0.92	0.22	0.98	0.08	0.85	0.06	*0.97*	*0.02*
Create the biggest number	0.98	0.14	0.59	0.45	0.98	0.02	0.78	0.12
Create the smallest number	0.94	0.22	0.62	0.46	0.98	0.02	0.78	0.12
Estimation	0.94	0.17	0.57	0.41	0.98	0.02	0.78	0.08
Find a number	0.96	0.15	0.59	0.41	0.96	0.15	0.59	0.41
Equations	0.95	0.17	0.40	0.40	0.98	0.01	0.74	0.05
Multiplication	0.95	0.19	0.45	0.40	1	0	0.75	0.01
Multiplication rules	0.99	0.22	0.69	0.43	1	0	0.91	0.04
Number line exact	0.97	0.14	0.69	0.43	1	0	1	0
Number line estimation	0.96	0.10	0.85	0.28	1	0	0.87	0.06
Parity	0.96	0.15	0.48	0.41	0.96	0.03	0.61	0.09
Read number	0.96	0.15	0.73	0.42	1	0	0.97	0.03
Series	1	0	0.63	0.45	0.98	0.01	0.81	0.08
Subtraction	0.75	0.33	0.23	0.34	0.73	0.05	0.54	0.04

Figure caption

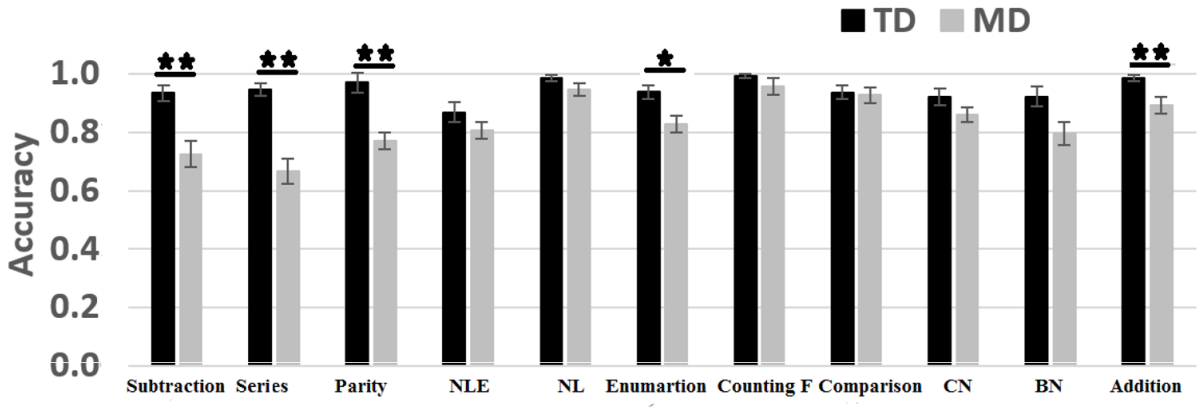
Figure 1.

A two-way repeated measures ANOVA was conducted on the response with subject matter (1- 11 for all the topics see Table 1) as the within-participants factor and group (MD or TD) as the between-participants factor for the children who were in the 1st grade during the corona closure. The effect of the subject matter was significant. First, TD participants were more accurate than MD participants in 1) addition in medium effect size 2) in indicating what the number that is between two numbers in medium effect size 3) in the enumeration in medium effect 4) in parity in large effect size 5) in series in large effect size 6) in subtraction in large effect size**.**

Figure 2.

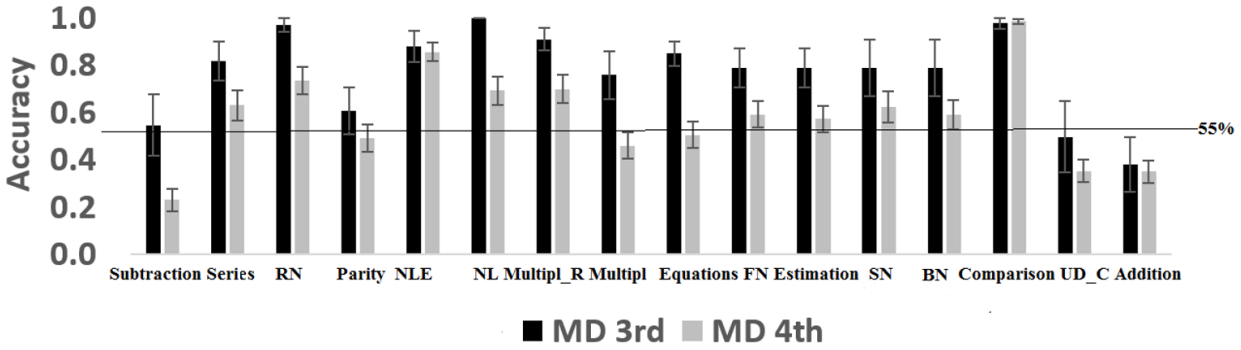
Grade comparison of responses for subject matters of the 2nd grade for students in the 3rd and the 4th grades, accuracy for MD. There was a main effect of grade. The MD children in the 3rd grade were more accurate than MD children in the 4th grade (3^{rd} = 0.78, SD = 0.26, 4^{th} = 0.58, SD = 0.38).

Figure 1.



Note. NL = number line, BN = between numbers, CN = close to number, counting F = counting forward. NLE = number line estimation.

Figure 2.



Note. RN = read numbers, multiplication R = multiplication rules, FN = find a number. NLE = number line estimation, NL = number line, SN = create the smallest number, BN = create the biggest number, UD C = change unit or decade.

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