MEASURING THE SPEED AND AMPLITUDE OF ACCOMMODATION IN SCHOOL-AGED CHILDREN

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Received: 31.07.2025.
Accepted: 03.03.2026.

ORIGINAL RESEARCH ARTICLE
UDK: 612.84:373.3
https://doi.org/10.31299/hrri.62.1.6

Abstract

Purpose: Visual accommodation, the eye's ability to shift focus between near and distant objects, is essential for functional vision in school-aged children. While normative data for the amplitude of accommodation are well established, the speed of accommodation — crucial for tasks such as copying from the board or switching between a screen and paper — remains largely undocumented. The aim of this study was to establish preliminary baseline data for both amplitude and speed of accommodation in typically developing children, thus, providing reference values that may support the early identification of visual difficulties in educational settings.

Methods: The study included 42 children (aged 6-14 years, grades 1-8) from a regular primary school in Zagreb. Visual functioning was assessed using near and distance Lea Numbers charts for visual acuity, monocular near point of accommodation (NPA), and convergence testing. Speed of accommodation was evaluated through a functional method: after reading near targets (40 cm), students were asked to shift their focus to distance targets (5 m), during which the time to recognition was recorded. Data were analysed using SPSS (Version 29), employing descriptive statistics, Pearson and Spearman correlations, as well as Wilcoxon Signed Rank and Kruskal-Wallis tests.

Results: The average accommodation speed was 1.17 seconds, with 57.1% of students responding within 0.5 seconds. While speed of accommodation significantly correlated with near and far visual acuity, it showed no association with convergence or NPA. Most children demonstrated an NPA that exceeded age-based expectations, particularly those in the third grade.

Conclusions and importance: These findings highlight the relevance of accommodation speed in functional vision. Establishing normative data in the future may improve screening protocols and guide educational adaptations for children with subtle visual inefficiencies that could impact learning outcomes. Future studies should expand on these findings with larger, more diverse samples.

Keywords: *accommodation, speed of accommodation, accommodation amplitude, school-aged children, functional vision.*

INTRODUCTION

In today's increasingly visual world, especially within educational settings, the ability to rapidly and clearly shift focus between objects at different distances is fundamental for school-aged children. This essential visual function depends on the process of accommodation — a reflex action of the eye that adjusts lens shape to focus on near and distant targets (Jung, 2019). It involves the adjustment of the lens's optical power, achieved through the contraction and relaxation of the ciliary muscle, which then alters the lens's curvature (Davies et al., 2024).

Although this process can be precisely defined in physiological terms, its true importance becomes evident in functional and everyday contexts. In school-aged children, for example, accommodation supports smooth transitions between visual tasks, such as shifting focus from a notebook to the blackboard, or from a digital screen to a peer across the room (Shukla, 2020). When this system is compromised, it may result in visual strain, blurred vision, or fatigue. This dysfunction may hinder daily tasks requiring visual attention and focus, contributing to challenges in activities such as reading, studying, and other near vision tasks (Zhengjing et al., 2024).

The efficiency of this system can be described by two major parameters: amplitude - the total accommodative capacity (Burns et al., 2014), and speed - the rapidity with which focus can shift between distances.

Although the amplitude of accommodation has been well documented in both clinical practice and academic literature, the speed of accommodation remains an underexplored area, particularly in school-aged children. Most existing literature and clinical protocols focus on measuring how strong the accommodative response is (i.e., the amplitude), while the time taken to execute that response is rarely assessed. A few studies have examined accommodation facility (Mechó García et al., 2024; Saikia et al., 2022), defined as the ability to shift focus repeatedly between near and far targets, using alternating plus and minus lenses. While accommodation facility provides insight into the flexibility and responsiveness of the accommodative system, it differs conceptually and methodologically from direct assessments of accommodation speed, especially under functional, real-world conditions. This gap is significant, especially considering that many visual tasks in classroom and digital environments depend not only on whether accommodation occurs, but also on how quickly it occurs.

In school settings, children constantly switch their visual focus between near and far targets (Shukla, 2020), for example, from notebooks to blackboards, tablets to teachers, or books to peers across the room. If a child's accommodative response is delayed or inefficient, even if the total amplitude is within the normal range, this can result in blurry vision, headaches, eye strain, and decreased visual comfort. These difficulties may not be detected in standard eye exams, especially if only static visual acuity or accommodation amplitude is tested. Therefore, studying the speed of accommodation may offer additional insights into functional vision problems that often go unnoticed, but can significantly affect educational performance.

Despite its importance, clinicians and educators lack access to norms that reflect the expected range of accommodation performance in typically developing children across different ages, specifically the speed of accommodation. Such reference values are especially important when it comes to differentiating between typical developmental variability and clinically significant delays or inefficiencies in visual function. Children's accommodative abilities evolve with age, and younger students may show different speed and flexibility patterns than older peers (Anderson & Stuebing, 2014). Understanding what constitutes "typical" performance is crucial, not only for diagnosis, but also for the planning of appropriate interventions, vision therapy, or classroom accommodations.

The rise of digital learning tools has significantly increased the demand for dynamic visual adaptability, with students expected to shift focus rapidly between screen content and other classroom visuals. However, widely adopted screening protocols still do not assess this aspect of visual function. As a result, a child may pass a standard vision screening, while continuing to experience functional difficulties due to slowed accommodative responses. After recognising this gap, recent discussions in child vision research have emphasised the importance of integrating functional vision assessments into routine screenings in order to better reflect the visual demands of modern educational environments (Bennett et al., 2019).

Objective

This study aims to address a critical gap in the literature by providing preliminary normative data on both the amplitude and speed of accommodation in typically developing school-aged children, using methods designed to reflect functional vision demands in everyday educational settings.

METHODOLOGY

After receiving approval from the Ethics Committee of the University of Zagreb, the Faculty of Education and Rehabilitation Sciences of the

University of Zagreb, and the Ministry of Science, Education, and Youth in Croatia, we contacted a regular primary school in the City of Zagreb. We assessed the visual functioning of 42 students, whose parents and the students themselves had given their written consent to participate in the study. The students attended different classes (from first to eighth grade, the last grade in primary school) and were categorised into different age groups (from 6 to 14 years). Most of them attended the lower grades (50%), 21.4% attended the third grade, and 28.5% attended the higher grades. The proportion of girls (52.4%) and boys in the sample was similar. No of the students reported having any visual problems, with the exception of refractive errors - 23.8% of them were wearing glasses. All students attended the regular primary school programme and had no known or suspected disabilities.

Assessments were conducted in a well-lit room, with bright daylight entering from the back of the students. Two assessors were present all the time, one was performing the assessment and the other assisted in specific tasks. If the student wore glasses, we tested all visual functions with prescribed correction, to reduce the effects of refractive errors. During the assessment, we also asked students to explain how they perceive visual information in different situations, such as when they switch focus from the notebook on the table to the blackboard or a presentation in the distance. Before testing, all participants demonstrated that they could reliably recognise and verbally name all Lea symbols at near and far distances. This ensured that delayed responses were not due to symbol recognition difficulties. The distance target was positioned centrally in the participant's primary gaze line, minimising the need for horizontal or vertical eye movements before recognition.

Many researchers describe methods for measuring the amplitude of accommodation by placing lenses with different dioptres in front of the eye or by measuring the near point of accommodation (NPA) by determining the closest distance from the eye at which the person can still see clearly. However, a standard method for measuring the speed of accommodation, especially when assessing functional vision, is not known to us. Therefore, we developed a method to assess the speed of accommodation based on the existing methods for measuring the amplitude of accommodation.

First, we measured the NPA of the sample monocularly and compared the results with existing norms, to estimate the power of accommodation. The NPA of the sample was assessed by asking participants to close one eye, while a letter printed on a plain visual target was presented directly in front of the open eye at a distance of 30 cm. A ruler was placed next to the participant's temple on the side of the eye being tested. Participants were asked to report what they saw on the target and whether the image was clear. They were informed that the letter would gradually move closer and would eventually become blurry, which is a completely normal occurrence. Participants were then instructed to signal when the image, i.e., the letter, became blurry. Once the participant indicated that the image was blurry, the number (in centimetres) on the ruler at the point where the visual target stopped was recorded (this number represents the NPA of the tested eye). Existing norms for the NPA were taken from Duane (1992).

Afterwards, we assessed the speed of accommodation during functional activity. Students read the Lea Numbers linear test at a distance of 5 metres, presented by Assessor A, who then noted the line with the smallest symbols that the students had read. Assessor B tested visual acuity with a Lea Numbers test at a near distance of 40 cm. After the students had read the entire line with the smallest symbols, i.e., their eyes were accommodated at close range, we asked them to read the symbols presented by Assessor A, i.e., the smallest symbols that they had already read at a distance of 5 metres. Assessor B measured the time (in seconds) using a stopwatch. The timer stopped when the participant correctly read the first symbol in the previously identified smallest symbol line. A full line of symbols was presented to prevent memorisation effects and to ensure genuine accommodation, rather than recall. If the students did not read immediately, we repeated the test. When we repeated the test, we used different symbols so that the students would not learn them by heart. In this case, we used the result of the second measurement. Assessors manually presented near and distance targets by holding them in a fixed position. Internal system delays were not present.

In addition to speed of accommodation, we assessed other visual functions that can potentially affect it: a) convergence by bringing interesting visual targets towards the root of the nose and measuring the distance (in cm) at which the child could not converge anymore; b) visual acuity using the Lea Numbers linear test at a distance of 5 m and the Lea Numbers linear test at a distance of 40 cm.

Functional vision results were analysed using IBM SPSS (Version 29). Based on the descriptive statistics, Pearson Correlation Coefficient was used to analyse the correlation between right and left eye NPA, given that the results were normally distributed. Furthermore, we used non-parametric tests for variables that did not meet the criteria of normality: Spearman Correlation Coefficient was used to calculate the correlations between different functions in the same sample, and Wilcoxon Singed Rank Test was used to calculate differences between groups.

RESULTS AND DISCUSSION

Our results show that the average speed of accommodation, measured by switching fixation from 40 cm to 5 m, was 1.17 s (SD = 1.12 s). Many students (57.1%) were able to read the symbols within 0.5 s after switching fixation to 5 m (Table 1). All students who needed more than one second after switching fixation to 5 m to see the symbols clearly described real-life situations in which they had a similar problem. For example, "when I play games on my mobile phone and want to see what's on a TV on the other side of the room, everything is blurry", "sometimes when I write my homework and then look out of the window, I can't see well", "sometimes I can't see the blackboard clearly when I lift my head from the notebook after writing for a long time". Similar symptoms have been reported across numerous studies. Students often struggle to shift focus between different distances - in a classroom setting, this typically presents as delayed visual clarity when switching one's gaze from the blackboard to the book and vice versa (Scheiman & Wick, 1994; Griffin & Grisham, 2002). Moodley (2008) noted that children with this difficulty are frequently among the last to finish copying tasks in class. The persistent blur experienced when initially changing focus, along with the effort required to quickly bring the target into clear view, is believed to be a key contributor to the asthenopic symptoms commonly reported by these individuals. As stated above, these symptoms include blurred vision at near distances, difficulty shifting focus between distances, visual fatigue or reduced reading endurance, diminished attention and concentration, frontal headaches or eye discomfort, and avoidance of near tasks. Due to the symptoms experienced by students with reduced speed of accommodation, it is essential to continue refining methods for assessing speed of accommodation from a functional perspective, as well as to establish normative data for students in mainstream educational settings. Standardised norms could help identify students whose visual functioning difficulties might otherwise go unnoticed and, in turn, support their learning through appropriate accommodations. For example, based on such results, teachers could make more informed decisions regarding the student's seating placement in the classroom. A variety of ergonomic guidelines are available to support sustained near work in daily life - such as the 20-20-20 rule, proper lighting conditions, appropriate sitting posture, and optimal workstation setup (Najmee et al., 2020). Moodley (2008) also emphasised that good visual acuity alone is not sufficient to ensure effective visual functioning in a classroom setting. Relying solely on visual acuity screening is both inadequate and potentially misleading, as a child who passes such a test is often assumed by parents and teachers to have a fully functioning visual system, despite the possible presence of underlying issues that could affect learning and classroom performance.

Table 1. *Percentage distribution of students based on speed of accommodation results (measured in seconds; binocular result)*

Speed of accommodation from near to far distance	% of students
0.5	57.1
1	16.7
2	14.3
3	9.5
6	2.4

Note: The time intervals in Table 1 correspond to observed natural clusters (0.5 s, 1 s, 2 s, 3 s, 6 s)

As previously mentioned, the method used to measure the speed of accommodation, particularly in the context of functional vision, is not familiar to us. Therefore, the obtained results cannot be directly compared with those of previous studies. The absence of standardised procedures, along with uncertainty regarding the respective roles of objective accommodation tests and subjective assessments of visual function, can pose several challenges related to study design and hinder meaningful comparisons across different studies (Vargas et al., 2019).

According to Scheiman and Wick (1994), a range of accommodative anomalies may be observed in children, including accommodative insufficiency, accommodative excess, accommodative infacility, ill-sustained accommodation, accommodative spasm, inaccurate accommodation, and increased latency. These categories are characterised by distinct symptoms and require tailored management approaches (Moodley, 2008). A commonly used method for assessing this condition involves asking the child to view a 6/7.5 letter target at their usual working distance and indicate when the letters appear clear after each flip of ±2.00 D lenses. The number of successful cycles completed within one minute is then recorded. In Moodley's study (2008), the overall prevalence of binocular accommodative infacility among the children screened was 30%. The highest failure rate was observed in 10-year-olds (40%), while the lowest was observed in 6-year-olds (13%). In the study by Najmee et al. (2020), near tasks did not produce any significant effect on accommodative facility. Measurements using both monocular and binocular accommodative facility tests showed no notable changes after near work, regardless of age group (adults or children) or refractive status (myopes or emmetropes). During near tasks, positive lenses introduce a vergence cue that makes it harder for the eye to fully relax accommodation, since the accommodation and vergence systems function together. As a result, even if accommodation relaxes, vergence assists in maintaining clear vision, which may explain the absence of a measurable effect on accommodative facility. On the other hand, López Bausili et al. (2017) emphasised that, based on their findings, accommodative facility measurements obtained using automated and manual flippers differ significantly and should not be used interchangeably.

The measured speed of accommodation correlated with visual acuity at near and far distance (near: $r_s(40) = -0.310$, $p = 0.046$; far: $r_s(40) = -0.375$, $p = 0.015$). These correlations were observed within the range of binocular visual acuity values recorded in the sample (0.63 - 1.3). Interestingly, the speed of accommodation had no significant correlation with the NPA of the students who participated in our study, nor with convergence (Table 2).

Table 2. *Spearman correlations between visual variables*

Variable	1	2	3	4	5	6
Convergence (cm)	—	.058	**− .435**	.209	.074	.181
Distance visual acuity		—	.203	**.308**	.243	− .375
Near visual acuity			—	**− .366**	− .300	**− .310**
Near point of accommodation (right)				—	**.773**	− .018
Near point of accommodation (left)					—	− .058
Speed of accommodation (s)						—

The NPA in the right eye (RE) and left eye (LE) was similar (average result: RE = 10.92 cm; LE = 10.38 cm). Only 16.7% had a NPA of 7 cm in at least one eye, as would be expected at primary school age. In addition, 73.8% of students had a NPA of 8 cm or more, ranging from 5 to 22 cm. The NPA of the right eye correlated significantly with that of the left eye ($r(40) = 0.809$, $p < 0.001$). Table 3 shows the distribution of monocular NPAs in centimetres; the values represent the closest distance at which clear vision was reported.

Table 3. *Percentage distribution of students over the results of the near accommodation point in cm*

Near point of accommodation (in cm)	% of students	
	Right eye	Left eye
5.0	4.8	2.4
6.0	7.1	7.1
7.0	14.3	16.7
8.0	7.1	7.1
8.5	2.4	2.4
9.0	7.1	7.1
9.5	2.4	4.8
10.0	9.5	4.8
11.0	7.1	14.3
12.0	7.1	9.5
13.0	4.8	9.5
14.0	2.4	-
14.5	2.4	-
15.0	7.1	4.8
15.5	-	2.4
16.0	2.4	2.4
17.0	4.8	-
18.0	2.4	2.4
20.0	-	2.4
21.0	2.4	-
22.0	2.4	-

A Wilcoxon signed-rank test was conducted to compare the NPA between eyes. The analysis showed no significant difference between the right eye (Mdn = 10) and the left eye (Mdn = 10, $Z = -1.08$, $p = .281$). Among the 42 students, 15 demonstrated a closer NPA in the left eye, 12 in the right eye, and another 15 had identical values in both eyes. These results indicate that the NPA was symmetrical between eyes based on the data from our sample.

Interestingly, the NPA of the right eye correlated significantly with near and far visual acuity (near: $rs(40) = -0.366$, $p = 0.017$; far: $rs(40) = -0.308$, $p = 0.047$), whereas the left eye showed no significant correlation with either near nor far visual acuity. None of the near accommodation points of the eye correlated with convergence.

We found no difference in speed of accommodation between students of different age groups. However, we found a difference in the NPA (RE: $H(4) = 14.699$, $p = 0.005$; LE: $H(4) = 12.135$, $p = 0.016$). A post-hoc analysis (Bonferroni) showed that only the third graders differed significantly from the first graders. The NPA of the third graders was much further away (RE: Me = 15 cm; LE: Me = 13 cm) than that observed in all other students, but the NPA values differed significantly only from those observed for the first graders (RE: Me = 7 cm; LE: Me = 7 cm). The NPA of the first graders was also much further away than expected for their age (7 cm).

The general reduction in power within the power spectrum of accommodation fluctuations has been attributed to an age-related decline in the elasticity of accommodative structures, aligning with the observed decrease in the speed of accommodation over time (Heron & Schor, 1995). Lockhart and Shi (2010) proposed three potential mechanisms underlying this age-related decline in dynamic accommodation: biomechanical rigidity of ocular structures involved in accommodation, increased central neural processing time, and reduced sensitivity of cone photoreceptors.

Speed of accommodation did not correlate with the NPA or convergence. This may reflect the difference between static accommodative capacity and dynamic accommodative response speed, which depends not only on lens biomechanics, but also on attention and processing speed. This highlights the need for tests focusing on speed of accommodation as it captures real-time functional efficiency.

Although the present study did not reveal significant differences in the speed of accommodation between the age groups examined, future research should include a larger sample size and consider comparing students who are at the very beginning of the formal education process with those who are about to complete their formal education, such as upper secondary school students.

As previously discussed, the NPA observed in the participants of the present study was significantly farther than expected for their age (7 cm). These findings deviate from established age-based standards, such as those reported by Duane (1922), who defined the expected amplitude of accommodation across different age groups. It is important to consider that today's educational environments have become increasingly dynamic and digitally oriented. As a result, students may have fewer opportunities for incidental accommodation exercises, for example, when copying from the blackboard, which could impact accommodative function. Nowadays, children tend to spend less time outdoors and less time focusing on distant objects, largely due to the shift towards more sedentary lifestyles, increased proportion of indoor activities, and prolonged screen use. These behavioural changes have been linked to a rising prevalence of myopia in children. Wu et al. (2016) similarly emphasised that ocular rigidity warrants further investigation, particularly in young adult emmetropes who may be at increased risk of developing late-onset myopia as a result of sustained near work demands. This is especially important since near work has become an integral part of both leisure and occupational activities in modern life, reflecting a shift in lifestyle patterns that alters mobility behaviours and may have implications for visual development and overall wellbeing.

Limitations

One of the key limitations of this study is the lack of standardisation of the method used to assess the speed of accommodation. Although this approach may provide insight into accommodative difficulties that can lead to functional problems in school settings, the absence of a validated and widely accepted protocol limits the reliability and comparability of the results. Further research is needed to refine this method and to evaluate its reliability and clinical utility. Another limitation is the unequal distribution of participants across age groups and the overall small sample size, which reduces the generalisability of the findings. Additionally, since all participants were recruited from a single primary school, the sample does not represent a randomised or demographically diverse population. Because of the small sample size, non-representative single-school recruitment, uneven age distribution, and the use of a newly developed functional method, these data should be interpreted as exploratory, rather than normative. The findings cannot be generalised and do not constitute preliminary normative values.

CONCLUSION

The findings of this study emphasise the importance of comprehensive vision screening that goes beyond visual acuity alone, since children with accommodative difficulties may otherwise remain undetected, despite these issues having a clear impact on their ability to perform academic tasks effectively. A reduction in accommodative efficiency can cause near tasks, such as reading and writing, to appear blurred, directly affecting learning outcomes in the classroom. Early identification and appropriate management of such difficulties are therefore essential to ensure that each child receives an equal opportunity to succeed in school. Professionals involved in education and vision care must work together to eliminate potential barriers to learning, particularly in the early school years. While accommodative facility provides insight into the responsiveness of the visual system, it is not equivalent to direct measurements of the speed of accommodation, especially under functional, real-life conditions. Since many school-related visual tasks rely not only on whether the eyes can accommodate, but also on how quickly they do so, this distinction is critical. Future research should include larger and more age-balanced samples in order to establish standardised assessment methods for measuring speed of accommodation and better understand its role in functional vision and academic performance.

Acknowledgments

We sincerely thank the school and all participating students for their involvement in the study, as well as for their patience and cooperation during the measurement process. Your contribution was invaluable to the success of this research.

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