

# ACCOMMODATIVE FACILITY TRAINING

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## ABSTRACT

### **Purpose**

The purpose of this paper is to characterize accommodative facility problems and related symptoms among otherwise healthy young pre-presbyopes showing accommodative dysfunction. The purpose is also to evaluate an accommodative facility training technique by studying the effect of the training on relative accommodation.

### **Subjects and methods**

Children aged 9–13 years, referred by School Health Care for near work-related problems and complaining of headaches, blurred vision, asthenopia, loss of concentration, and avoidance of near activity, were selected. Only children with reduced negative relative accommodation (NRA) and positive relative accommodation (PRA) and/or very slow accommodative facility were included.

For accommodative facility training, the subjects used an accommodative facility training technique until they reported that the symptoms had disappeared.

### **Results**

In all children, the symptoms gradually decreased and finally disappeared during the training period. Despite some individual variations, our data show a significant increase in both mean NRA and mean PRA among all children characterized with accommodative infacility due to an impaired relative accommodation.

### **Discussion**

The results indicate that accommodative facility training is an effective method resulting in loss of symptoms and that it also has a real effect on the amplitude of relative accommodation in patients with impaired relative accommodation. Because accommodative infacility may result in asthenopic symptoms, it is of great importance to identify the dysfunction to prevent unnecessary near vision problems.

## **APPENDED PAPERS**

This work is based on following papers:

### **Paper I**

Sterner, B., Abrahamsson, M., Sjöström, A. (1999). Accommodative facility training with a long term follow up in a sample of school aged children showing accommodative dysfunction. *Documenta Ophth* 99: 93 – 101.

### **Paper II**

Sterner, B., Abrahamsson, M., Sjöström, A. The effects of accommodative facility training on a group of children with impaired relative accommodation - a comparison between dioptric treatment and sham treatment. *Ophthalmic and Physiological Optics*. Manuscript accepted (15 May, 2001).

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## ABBREVIATIONS

AC/A	Accommodative convergence/ accommodation
C	Convergence
CA	Convergence accommodation
cpm	Cycles per minute
D	Diopters
DA	Dark accommodation
NRA	Negative relative accommodation
NRM	Negative relative movement
PC	Point of convergence
PRA	Positive relative accommodation
PRM	Positive relative movement
SD	Standard deviation
TA	Tonic accommodation



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## INTRODUCTION

### The mechanism of accommodation

*Accommodation* is the ability of the eye to change the refractive power of the lens and automatically focus objects at various distances on the retina. This accommodative process (Figure 1) include contraction of the ciliary muscle, which releases the tension on the zonular fibers allowing the elastic lens capsule to increase its curvature, especially that of the front surface. Along with these changes, an increase in the thickness of the lens, a decrease in its equatorial diameter, and a reduction in pupil size take place (Brown, 1972) (Figure 2).

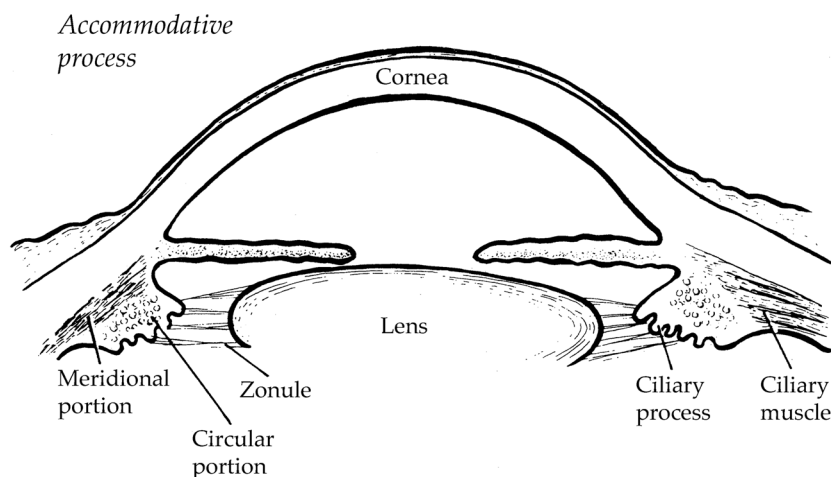


Figure 1. The accomodative process.

Accommodation is measured in diopters (D), that is, in terms of the reciprocal of the fixation distance. Thus, if the fixation distance is 1 m, the accommodation is said to be 1 D; if it is 0.5 m, the accommodation is 2 D, if 0.33 m, then 3 D, and so forth.

The furthest distance at which an object can be seen clearly is called the *far point* (*punctum remotum*). In order to see such an object the eye is in a state of rest, the ciliary muscle is relaxed, and the refractivity is at minimum.

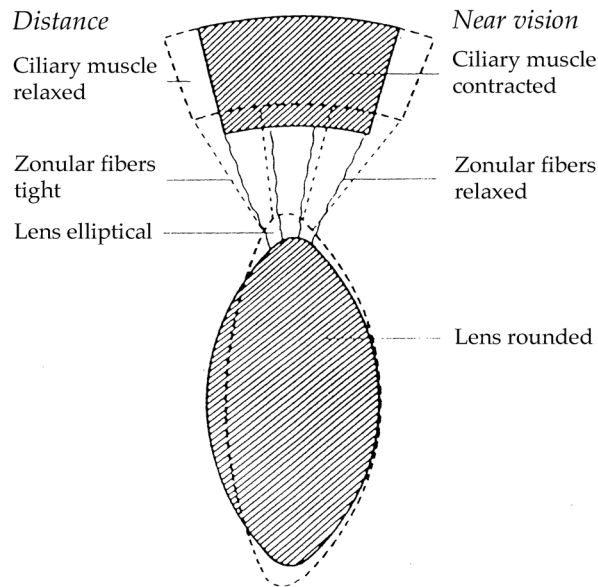


Figure 2. Schematic picture of the lens and the ciliary muscle when relaxed during "distance" vs accommodated during "near" vision.

When maximum accommodation is in force, the nearest point which the eye can see clearly is called the *near point* (*punctum proximum*). The difference between the refractivity of the eye in the two conditions – when at rest with minimal refraction, and when fully accommodated with maximal refraction – is called the *amplitude of accommodation*. In order to accurately perform visually guided daily tasks, it is necessary for the accommodative system to be dynamic, fast, and precise to ensure a well-focused image on the retina.

It has been known for over 50 years that, under certain conditions, accommodative activity in the eyes may act as a stimulus which produces a change in the relative position of the visual axes as a response (Morgan, 1944). When the angle formed by the visual axes increases this is called *convergence*, and when it decreases, we call this *divergence*. In addition, with fixation at near pupillary constriction, *miosis* occurs (Von Noorden, 1985). The synkinetic association between accommodation, convergence, and miosis during fixation at near may be termed the *near vision complex*.

The accommodative act is normally accompanied by a change in convergence because of the synkinetic association between the ciliary muscle and the medial recti (Duke-Elder, 1971). An accommodative stimulus acts as a trigger which

excites innervational mechanisms for convergence. This response of convergence due to the accommodation constitutes *accommodative convergence*. However, due to the synkinetic association, a stimulus for convergence can also provoke an accommodative impulse called *convergence accommodation*. The fact that the eyes can converge without an impulse to accommodate, but that accommodation cannot occur without an impulse for convergence, raises the question which of these functions is dominant.

## **Accommodative measurements**

### **Stimuli to accommodation**

The characteristics of effective accommodative stimuli are central to our understanding of the accommodative system. There are a number of different accommodative stimuli which to varying degrees stimulate accommodation (Sivak & Bobier, 1978; Kruger & Pola, 1985; McLin Jr *et al.*, 1988; Comerford & Thorn, 1990; Siderov & Johnston, 1990; Rosenfield *et al.*, 1991; Gray *et al.*, 1993; Mathews & Kruger, 1994; Rosenfield & Cohen, 1995; Kruger, Mathews *et al.*, 1997):

Blur of the object

Proximity of the target

Changing target size

Chromatic aberration

Convergence of the eyes

Spatial frequency

These are all different stimuli to accommodation, with blur of the object having the greatest impact as accommodative stimulus, though dependent on visual acuity (White & Wick, 1995). However, an important implication is the completely different character of these accommodative stimuli, which can act together as well as individually. The inherent differences between the stimuli therefore require that different methods be used to describe them.

## Amplitude of accommodation

The ability to accurately focus a visual target at varying distances exists to some extent from birth (Banks, 1980a), but improves rapidly in the first 3–6 months of life (Banks, 1980b; Howland, 1982–83; Hainline *et al.*, 1992; Bobier *et al.*, 2000). A small child is normally able to focus from infinity down to a distance close to the eyes because of a high level of accommodative ability. However, evidently accommodation and convergence are not automatically linked from the start (Figure 3).

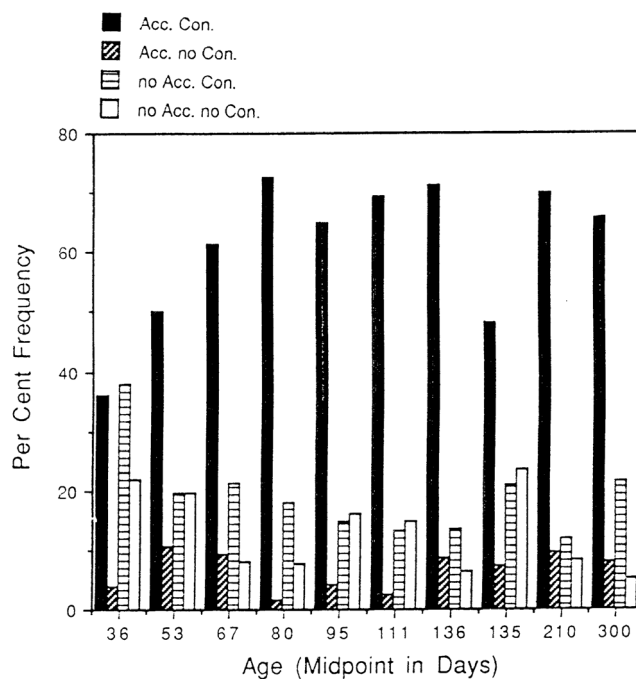


Figure 3. Frequency of infants displaying different styles of accommodation and convergence. We have used percentages because the number of infants in each group varies. The age groups used are 26–45 days (mid-point 36 days), 46–59 days (mid-point 53 days), 60–73 days (mid-point 67 days), 74–87 days (mid-point 80 days), 88–101 days (mid-point 95 days), 102–120 days (mid-point 111 days), 121–150 days (mid-point 136 days), 151–180 days (mid-point 165 days), 181–240 days (mid-point 210 days), and 241–365 days (mid-point 300 days). The black columns show the percentage of infants who accommodated and converged monotonically; the obliquely striped columns represent infants who accommodated but did not converge monotonically; the columns with horizontal hatching represent infants who converged but did not accommodate; and finally, the white columns represent infants who neither accommodated nor converged monotonically (Hainline *et al.*, 1992).

In 1912, Duane presented his result on the accommodative amplitude among 500 subjects (i.e., 1000 eyes) aged 8 to 70 years. The given data are still commonly used as normality for accommodative amplitude in relation to age.

A formula, (average amplitude =  $18.5 - 0.3 (\text{age})$ ), based on Duane's data predicts the range of accommodative amplitude expected at a given age (Woodruff, 1987) (Figure 4). There were only 33 children between 8 to 12 years of age why the reliability of this "normality" for these ages is discussed (Turner, 1958; Wold, 1967; Kragha, 1986). However, based on this formula, a 3 year old child is expected to have an average accommodative amplitude of 17.6 D. A study by McBrien and Millodot, 1986, shows different data on accommodative amplitude, linked to ametropia (i.e., late-onset myopes: mean = 10.77 D; earlier-onset myopes: mean 9.87 D; emmetropes: mean 9.28 D; and hyperopes: mean 8.63 D) among 18-22-year-old subjects. This is an issue to consider when discussing normality of the accommodative amplitude.

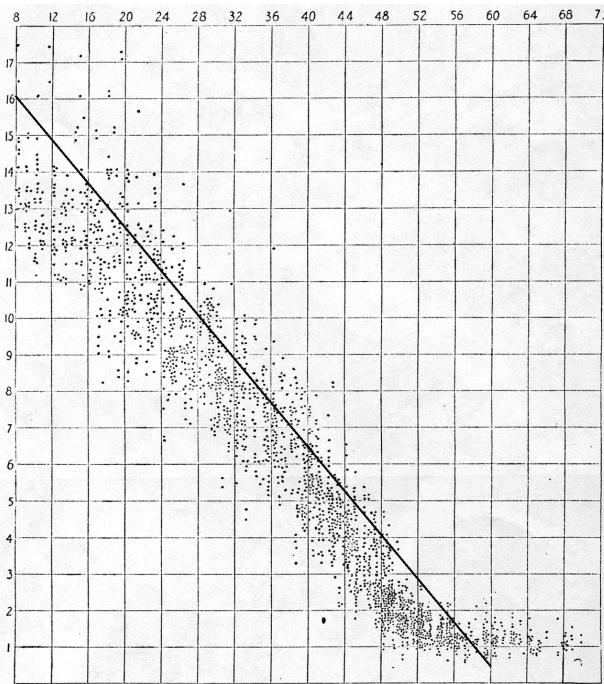


Figure 4. Diagram from Duane (1912) showing the relation between age ( $x$ -axis) and accommodative amplitude in diopters ( $y$ -axis), with each dot representing the maximum accommodative power of an individual eye at a given age. The straight line is a plot of the prediction formula (average amplitude =  $18.5 - 0.3 (\text{age})$ ) by Woodruff (1987).

### Facets of accommodation

The accommodative function is normally explained, although insufficiently, by describing the accommodative amplitude and its dioptric value. However, the accommodative function is more complicated than that. The accommodative

system is complex; the different facets of the accommodative function are described and explained elsewhere in the literature (Rouse *et al.*, 1984; Wick & Hall, 1987; Michaels, 1987; Rosner & Rosner, 1989; Von Noorden & Avilla, 1990; Ebenholtz, 1991; Miwa & Tokoro, 1993).

Different facets of the accommodative function, together with accommodative amplitude, are listed below:

Tonic accommodation

Lag of accommodation

Convergence accommodation

Accommodative facility

Relative accommodation

These facets differ greatly from each other with regard to function. They require different methods of examination and they are not explained by the same dioptric values; nor is a unified system of measurement used for their dioptric results.

Each of the accommodative facets listed above is described below. However, in this thesis, I will concentrate on accommodative facility and relative accommodation with regard to function, method of examination, and expected dioptric value. In the case of failure of function, associated symptoms will be described.

### ***Tonic accommodation***

Tonic accommodation (TA), or dark accommodation (DA) (Tsuetaki & Schor, 1987; Rosner & Rosner, 1989; Ebenholtz, 1991; Rosenfield *et al.*, 1992; Chiu & Rosenfield, 1994; Rosenfield *et.al.*, 1994), is the passive state of accommodation in the absence of a stimulus, that is, when the eye is either in complete darkness, or when it is looking at a bright empty field (open-loop). One method of measuring the open-loop is by using an objective infrared optometer (Gray *et al.*, 1998).

### *Lag of accommodation*

The amount by which the accommodative response of the eye is less than the dioptric stimulus to accommodation is defined as *accommodative lag* (Rouse *et al.*, 1984; Wick & Hall, 1987; Goss & Zhai, 1994). Clinical measurement of accommodative lag at near is typically done using dynamic retinoscopy. This is an objective method in which the patient views a nearpoint target, while the examiner adjusts the lens power or his or her distance from the patient.

### *Convergence accommodation*

Convergence accommodation is normally described by the ratio between convergence accommodation and convergence, or the CA/C ratio (Morgan, 1944). The ratio is a measure of the effect of a change in convergence on accommodation. It is expressed as the change in accommodation (in D) for each change in convergence (in prism D) (Tsuetaki & Schor, 1987).

### *Accommodative facility*

Accommodative facility is the ability to rapidly change the refractive power of the lens to various focus distances (Wick & Hall, 1987) while maintaining a requisite angle of convergence (binocular) or eliminating the influence of convergence (monocular). This ability is important when changing fixation from near to distance, and back again.

Clinically, accommodative facility is measured using lenses that stimulate (minus) or inhibit (plus) accommodation. Any combination of lens power can be used for evaluation, but empirical testing has indicated that  $\pm 2.00$  D is a reasonable choice (McKenzie *et al.*, 1987). The testing procedure uses  $\pm 2.00$  D lens pairs mounted in a flipper frame. A “flipper” is a holder with two minus lenses and two plus lenses (Figure 5).

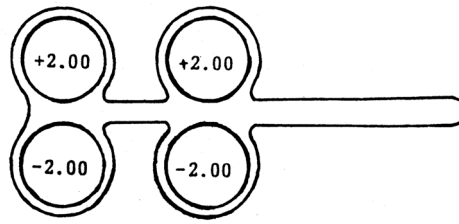


Figure 5. Flip lenses.

The subject focuses through one pair of lenses at an object at near distance (40 cm). When the object is clearly focused, a flip is quickly performed to the other lens pair and the subject focuses through them. This is then repeated and the number of cycles completed in 1 minute (cpm) is recorded as the *accommodative facility*.

Normative data on monocular as well as binocular accommodative facility have been collected on both adult pre-presbyopic populations (Zellers *et al.*, 1984; Siderov & Diguglielmo, 1991) and young school children (Hennessey *et al.*, 1984; Scheiman *et al.*, 1988; Jackson & Goss, 1991a) (Table 1). In the study by Siderov & Diguglielmo (1991), adults between 30 years and 42 years of age showed a mean and SD for the  $\pm 2.00$  flip task of  $1.2 \pm 2.1$  cpm binocularly. Another study, by Zellers *et al.* (1984), of adults aged 18–30 years, had a mean and SD for the binocular  $\pm 2.00$  flip task of  $7.72 \pm 5.15$  cpm. Two studies of young school children aged 6–12 reported means and SDs on the binocular  $\pm 2.00$  flip task. Results were  $5.0 \pm 2.7$  cpm in one study (Jackson & Goss, 1991a), and  $3.83 \pm 2.5$  cpm in another (Scheiman *et al.*, 1988). One reason for the lower mean cpm in this age group, as compared with the results for 18–30-year-olds, may be the difference in instructional sets. Instead of the subjects holding the flip lens, as with the adult groups, the examiner held it. One also have to consider possible differences with respect to the age and the time necessary for saying “clear” (Kedzia *et al.* 1999).

Table 1. Binocular accommodative facility in cpm ( $\pm$  SD) using  $\pm 2.00$  D flip lenses.

	Age 6-12 years	Age 18-30 years	Age 30-42 years
Jackson & Goss	5.0 $\pm$ 2.7		
Scheiman et al.	3.83 $\pm$ 2.5		
Zellers et al.		7.72 $\pm$ 5.15	
Siderov & Diguglielmo			1.2 $\pm$ 2.1

The monocular (Rouse *et al.*, 1989) and binocular (Rouse *et al.*, 1992) accommodative facility rates have previously been studied in an attempt to establish normative data and cutoff values which differentiate symptomatic from asymptomatic subjects (McKenzie *et al.*, 1987; Garcia *et al.*, 2000). The 1-minute testing method appears reliable if the initial rate is lower than 3 cpm. For patients whose initial rate is between 3 cpm and 8 cpm, extended testing (i.e., 1–2 minutes' additional testing) may be needed to arrive at an accurate diagnosis.

### ***Relative accommodation***

The total amount of accommodation which can be exerted while the convergence of the eyes is fixed is called *relative accommodation* (Morgan, 1944). This can be either *positive relative accommodation* (PRA) or *negative relative accommodation* (NRA). The PRA is the amount of accommodation in excess of the accommodation needed for convergence and the NRA is the amount of accommodation below that of convergence (Gettes, 1957) (Figure 6).

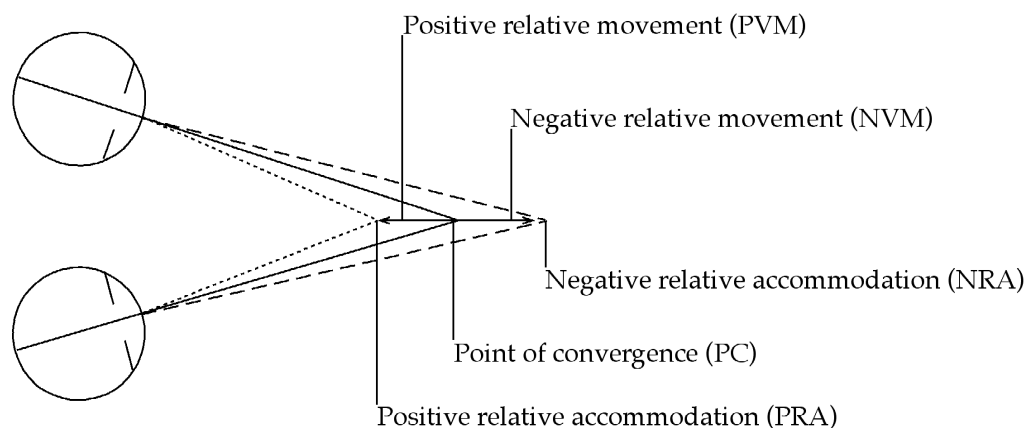


Figure 6. The relation between positive relative accommodation (PRA), negative relative accommodation (NRA), and the point of convergence (PC). The dotted lines in the Figure describe the point the accommodation is focused to when a plus lens (for NRA) or a minus lens (for PRA) is added without changing the convergence stimuli. The positive relative movement (PRM) and negative relative movement (NRM) describe the direction of the different dioptric focus change movements of the PRA and the NRA in relation to the PC.

Hung & Ciuffreda (1994) describe how relative accommodation is measured. In assessing accommodative flexibility, with a constant convergence stimulus and under binocular fusion, the accommodative stimulus was binocularly decreased. This is done by starting with positive lenses and continuing in +0.25 D steps over the distance correction, with the vergence stimulus (at 40 cm) held constant, until the first slight sustained blur subjectively noted by the patient. The decreased amount of accommodative stimulus at this point is referred to as the *NRA value*. If the accommodative stimulus is now increased binocularly with negative lenses in -0.25 D steps until the first slight sustained blur is again noticed, the increased amount of accommodative stimulus at this point is referred to as *PRA*.

Means for NRA and PRA in 800 subjects have been presented in Goss & Zhai (1994), all of whom had an accommodative amplitude of 5.00 D or more, to give  $+2.00 \pm 0.50$  D and  $-2.37 \pm 1.12$  D, respectively. In the same study, 1000 school children from first to twelfth grade had a mean NRA of  $+1.75 \pm 0.56$  D and a mean PRA of  $-2.37 \pm 1.00$  D.

An important question at this point is what happens with the NRA/PRA value if we add prism D? Is it possible, for example, to increase the NRA value if we add base in prism? We know by hearsay that 6 prism D with prismatic base in

will increase the NRA value by approximately +0.50 D, but we could not find any evidence in the literature for this relation.

Due to the near vision complex (page 2), a certain portion of convergence is linked when accommodation is in force. The relation between the dioptric change of the accommodation and the prismatic change of the convergence is called the *accommodative convergence/accommodation (AC/A) ratio*. The AC/A ratio describes how much accommodative convergence is activated by an accommodative change of 1 D. In Table 2, the relationship between high, normal, and low AC/A ratios and the different convergence stimuli is described. Because of the difference in convergence stimuli, according to the AC/A ratio, it is essential to take the AC/A ratio into consideration when the accommodative function is measured and accommodative dysfunctions are being described.

Table 2. The relation between the AC/A ratio and the convergence stimuli when accommodation is changed by  $\pm 2.00$  D.

AC/A	AC/A ratio (prism D/D)	Convergence stimuli (prism D)
"High"	>5	> $\pm 10.0$
"Normal"	3 to 5	$\pm 6.0$ to $\pm 10.0$
"Low"	<3	< $\pm 6.0$

The normal range of the AC/A ratio is between three and five. Values above five are considered to denote excessive accommodative convergence and values under three an insufficiency (von Noorden 1990).

In individuals with high AC/A ratio the larger convergence stimuli induced by the changed accommodation may effect the measured treshold of the PRA and/or the NRA if the fusional vergence is at its limit.

If a prismatic lens is added in front of the eye and thereby changes the convergence stimuli, a change in accommodation will be expected. If we add a base in prism in front of the eye, the convergence stimuli will change to a point further away from the eye. As a result, the PRA value will decrease and the NRA value will increase.

The correlation of PRA with prismatic base in blur at near distance is to be expected because the amount of PRA a person can exert may be limited by his or her negative fusional vergence (i.e., divergence with fusion at the same stimuli) capability. Likewise, there is a correlation between NRA with near base-out blur because NRA may be limited by the amount of available positive fusional vergence (i.e., convergence with fusion at the same stimuli) (Jackson & Goss, 1991a).

Tests for PRA and NRA are very helpful in determining accommodative dysfunction (Weisz, 1983). A low NRA reveals accommodative spasticity; a very low PRA, on the other hand, suggests that the focusing system may be prone to tiring after concentrated near work.

### Accommodative measurements

The different accommodative components listed above require different methods of measuring accommodative ability and giving dioptric results. There is no method in use that describes the complete accommodative function or even some of the functions put together, nor do we use the same measuring system for the different dioptric results. Since there is therefore no method to combine the results of various accommodative components, we need to find out whether any existing method can be useful in identifying an accommodative dysfunction of any kind. The following tests are in use:

Amplitude tests:            *Donders push-up method*: This makes use of a RAF ruler (Figure 7).

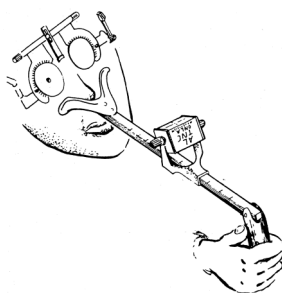


Figure 7. Instrument for measuring the closest focus distance in diopters (D), the RAF ruler.

*Minus to blur:* Here, minus lenses are added at far distance, monocularly or binocularly, until blur at distance occurs.

Facility tests: *±2.00 D flip lens test:* This is used to measure the exertion and relaxation change of the accommodation in cpm (see also page 8, "accommodative facility", Figure 5).

*Relative accommodation:* In this test, the accommodative flexibility is assessed by changing the accommodative stimulus.

Objective tests: *Dynamic retinoscopy:* This is used to establish the degree of lag of accommodation (Leat & Gargon, 1996).

*Infrared optometers, e.g., a power refractor:* These are used to examine the eyes for defects of refraction.

Miscellaneous tests: *Binocular cross cylinder at near distance:* With this, the magnitude of the dioptric reading addition is established while the subject focuses a near distance object.

*Comparing cycloplegic and manifest refraction:* This is done to objectively look for refractive differences (e.g., accommodative spasm) using retinoscopy.

## **Accommodative dysfunction**

### **Presbyopia**

The ability to accommodate slowly deteriorates through life and during the fifth decade of life, insufficient accommodative ability becomes a manifest problem resulting in emmetropia. The amplitude of accommodation has decreased to a level of approximately 4 D (Koretz & Handelman, 1988) and focusing at normal reading distance either requires longer arms or proper optical aids. This condition is called *presbyopia* (Duane, 1912) and the decrease of the

accommodative amplitude continues until the amplitude of accommodation almost reaches 0 D.

The development of presbyopia is not well understood, and there are theories which attempt to explain its mechanism (Bito, 1988; Fisher, 1988; Atchison, 1995; Beers & Van der Heijde, 1996). Although presbyopia means “vision of old age”, its onset rarely can be chronologically defined because it varies with coexisting ametropia, illumination, target size and distance, the effect of drugs, arm length, geographic latitude, and psychological factors (Michaels, 1987).

### **Dysfunctions**

The accommodative system at young age is fairly flexible and resistant to fatigue (Berens & Sells, 1944). However, in clinical practice, accommodative dysfunction is common among pre-presbyopic and presbyopic patients. Often, patients complain of symptoms that appear when doing near distance work. The refractive status can be emmetropic or slightly ametropic, but this is not always in relation to the patients' complaints. There is, as mentioned previously, no simple standard procedure for examination of the accommodative system including all its facets. Because of the lack of such method, and the fact that we do not have any simple method to treat accommodative problems, the accommodative system is not routinely examined. Still, it is of great importance to identify a dysfunction so that unnecessary near vision problems may be prevented. In young individuals, it is essential to identify any accommodative deficiencies as soon as possible after school start. Because the focusing system of the eyes has a contribution in learning disability (Flax, 1970; Sucher & Stewart, 1993), any accommodative deficiency can make it unnecessarily difficult for the child to read and develop in school. If the child does not prevent his or her difficulties to accommodate he or she may always harbor a dislike for near distance work. Therefore, we need to find a simple and easy-to-use method that identifies and diagnoses an accommodative dysfunction.

It can be difficult to group accommodative dysfunctions because the boundaries are often unclear. However, clinically it is useful to separate anomalies of

accommodation into one of five distinct syndrome categories (Walsh & Hoyt, 1969; Duke-Elder, 1971):

Insufficiency of accommodation

Fatigue of accommodation

Spasm of accommodation

Paresis of accommodation

Infacility of accommodation

These five syndromes all constitute different accommodative disorders, with a different impact on the accommodative function (Table 3).

### **Asthenopia**

Different symptoms associated with accommodative dysfunction are listed in Table 3. Asthenopia is a term used to describe eyestrain or symptoms associated with the use of the eyes. The causes of eyestrain are numerous and include sustained near vision, either when the accommodative amplitude is low or if hypermetropia is uncorrected, aniseikonia, astigmatism, pain in the eye, heterophoria, ocular inflammation, hysteria, uncorrected presbyopia, improper illumination, and retinal disease (Millodot, 1986). However, accommodative infacility may also result in asthenopic symptoms (Hennessey *et al.*, 1984).

Table 3. Diagnostic criteria with respect to accommodative dysfunction, and the incidence of related findings and symptoms.

● Occasional incidence  
●● Frequent incidence

Diagnosis	Reduced accommodative amplitude	Reduced ciliary muscle function	Reduced relative accommodation	Reduced accommodative facility	Associated symptoms *
Insufficiency of accommodation	●●	●		●	●●
Fatigue of accommodation	●	●●	●●	●●	●●
Spasm of accommodation	●●	●●	●●	●●	●●
Paresis of accommodation	●●	●●	●●	●●	●●
Infacility of accommodation		●●	●●	●●	●●

\* Asthenopia, blur, headaches, diplopia, accommodative facility problems, photophobia, and reading problems are the most frequently reported symptoms indicating accommodative dysfunctions (Hoffman and Rouse, 1980; Daum, 1983; Hennessey *et al.* 1984).

*Insufficiency of accommodation* is a condition in which the amplitude of accommodation is chronically below the lower limits of the expected amplitude of accommodation for the patient's age (Von Noorden *et al.*, 1973; Daum, 1983). Morgan (1944), in describing various diagnostic criteria, states that insufficiency of accommodation occurs when the accommodative amplitude is reduced by more than 2 D below Duane's expected values for age (1912). Symptoms include inability to focus on near objects or to sustain clear vision for a reasonable period of time. A study on nine children aged 9–16 years (Matsuo & Ohtsuki, 1992) with low accommodative amplitude in both eyes reports that the subjects had severe complaints of asthenopia, diplopia, and difficulty in reading. The clinical recognition of accommodation insufficiency is important in preventing unnecessary frustration in young school children (Chrousos *et al.*, 1988).

*Fatigue of accommodation* is described as the inability of the ciliary muscle to maintain contraction while viewing a near target, with a resulting shift in accommodation toward the far point (Pigion & Miller, 1985; Owens & Wolf-Kelly, 1987; Schor & Tsuetaki, 1987).

*Spasm of accommodation* is a constant or intermittent involuntary and inappropriate ciliary contraction (Rutstein *et al.*, 1988; Goldstein & Schneekloth, 1996). It may be unilateral or bilateral. Symptoms include distance and/or near blur, visual distortion, a drawing or pulling sensation, and possibly intermittent or persistent diplopia (Michaels, 1987). Also, a dynamic retinoscopy shows a lag of  $<\pm 0.00$  D (Rouse *et al.*, 1984).

The most common cause for *paresis of accommodation* is topical cycloplegia, whether deliberate or inadvertent. Such palsy is generally unilateral, transient, and evident from patient's history (Michaels, 1987; Mutti *et al.*, 1994). Accommodative paresis can also be functional owing to weakness or fatigue of the ciliary muscle (Duke-Elder, 1971).

*Infacility of accommodation* is the condition in which the ability to rapidly change accommodation, from far to near distance, is failing or in which a rapid change of accommodation induces symptoms such as asthenopia, headache, and blur (Hennessey *et al.*, 1984). It differs from accommodative insufficiency in that clear vision is eventually achieved (Michaels, 1987). Diagnostic criteria for accommodative infacility are a NRA and PRA of  $<\pm 1.75$  D (Morgan, 1944; Hennessey *et al.*, 1984) and/or facility test using the  $\pm 2.00$  flip test showing 1 SD below the mean, of 3 cpm (Hennessey *et al.*, 1984). If changing fixation from distance to near takes more than 1 second an abnormal condition is likely to be present (Daum, 1983).

However, due to the accommodative syndromes listed above, a person's ability to perform a nearpoint task may be impaired if, for example, his or her accommodative facility is deficient, despite having sufficient accommodative amplitude (Hennessey *et al.*, 1984). It is therefore essential to identify the exact cause of accommodative dysfunction in order to alleviate symptoms, improve accommodation efficiency, and decide on the type and extent of treatment.

## Accommodative facility therapy

Accommodative dysfunction is a common visual anomaly and the symptoms generally occur during the performance of nearpoint tasks (Daum, 1984). Dysfunctions of accommodation, which have been treated by optometric intervention, are usually clinically classified as those dysfunctions mentioned previously, namely accommodative insufficiency, accommodative spasm, accommodative fatigue, and accommodative infacility (Suchoff & Petito, 1986), with insufficiency and infacility as the most frequent forms of dysfunction (Daum, 1983). The treatment of a dysfunction is generally a plus lens addition or orthoptic exercise (Hoffman, 1982; Bobier & Sivak, 1983; Cooper *et al.*, 1987).

A plus lens addition is recommended in cases of an excessive lag in accommodation, very low PRA ( $< -1.5$  D), difficulty in performing the minus lens part of the  $\pm 2.00$  D facility test, or fatigue during the facility test (Weisz, 1983). The prescription can be in the form of either normal reading glasses or a bifocal solution.

Orthoptic exercise is indicated when there is a spasticity in the accommodative system or the accommodative system is poorly controlled (Cooper *et al.*, 1987). It is also indicated if the patient cannot clear the initial plus lens flip on the  $\pm 2.00$  D or if the NRA is low (i.e.,  $< +1.5$  D). Orthoptic exercise is a sequence of activities individually prescribed and monitored by the doctor to develop efficient visual skills and processing. One particular method in orthoptic exercise is using the flip lens technique. A “flipper”, as previously mentioned, is a holder with two minus lenses and two plus lenses (Figure 5). The subject focuses through one pair of lenses at an object at near distance (40 cm). When the object is clearly focused, a flip is quickly performed to the other lens pair and the subject focuses through this. The process is then repeated.

There is scientific and clinical evidence to support the efficacy of using facility therapy techniques to “strengthen” or improve accommodative function (Wold, 1978; Liu *et al.*, 1979; Weisz, 1979; Levine *et al.*, 1985; Hung *et al.*, 1986; Rouse, 1987).

## OBJECTIVES

### **Overall aim**

The aims of the present work have been firstly, to characterize accommodative facility problems and related symptoms among otherwise healthy children presenting with accommodative dysfunction, and secondly, to evaluate an accommodative facility training technique. It is important to outline the results of the training technique before conclusions can be drawn about using the technique on visually impaired pre-presbyopes with accommodative dysfunction.

### **Specific aim: Paper I**

The specific aim of this study was to examine the effect of flip lens training on the accommodative function in a group of children with accommodative dysfunction and symptoms such as asthenopia, headache, blurred vision, and avoidance of near activity. Another aim was to study whether flip lens training increases accommodative facility, and to establish whether it may have a positive effect on the subjects' asthenopia and related problems also in the long term.

### **Specific aim: Paper II**

The aim of Paper II was to further study the effect of accommodative facility training on relative accommodation. As part of the study, a comparison was made between traditional dioptric flipper treatment and a sham flipper treatment to establish whether it was the treatment as such that affected the subjects' accommodative performance or whether the additional caregiving of the children had an influence.



## SUBJECTS AND METHODS

### Subjects: Paper I

Altogether 38 children aged 9–13 years were selected for this study. The children, who came from a highly motivated group, were referred by School Health Care for near work-related problems and for complaints of headaches, blurred vision, asthenopia, loss of concentration, and avoidance of near activity. We included only children with reduced NRA and PRA and/or a very slow accommodative facility. (Table 4 show the values of the NRA and the PRA among the children in this study compared to the diagnostic criteria for accommodative infacility from Morgan, 1944; Hennessey et al., 1984).

*Table 4.* Mean relative accommodation ( $\pm$  SD) before training and for controls compared to the values presented by Morgan, 1944 and Hennessey et al., 1984 as the diagnostic criteria for accommodative infacility.

	Before training	Controls	Morgan, 1944; Hennessey et al., 1984
Mean NRA	+ 1.25 $\pm$ 0.4 D	+ 2.0 $\pm$ 0.2 D	< + 1.75 D
Mean PRA	- 1.3 $\pm$ 1.0 D	- 3.9 $\pm$ 1.3 D	< - 1.75 D

Before entering them into the training program, their accommodation, cycloplegic refraction, and visual acuity at distance (decimal notation) were examined. In all children, binocular vision, stereopsis, and motility were tested by an orthoptist. All the parameters were in normal range. Before the long-term follow-up examination 2 years after the conclusion of accommodative facility training, all of the 38 children in the study were interviewed by telephone.

Normative data were established using 24 voluntary controls aged 9–13 years.

**Subjects: Paper II**

Thirteen Swedish children, five girls and eight boys aged 9–11 years, were included in the study. They were referred by the same criteria as used for the children in Paper I.

**Methods: Papers I and II**

To establish relative accommodation, both positive and negative, we used the method described in Hung & Ciuffreda (1994).

For accommodative facility training, the children were requested to use a flipper while focusing a text at 40 cm for 3 minutes at least five times a day. We started with a flipper power the children almost could not focus through and then, increased the magnitude of the lenses in the flipper by 0.50 D steps at a pace the children could comfortably put up with. In Paper II, the children in the sham group started with 2 weeks of training with plano lenses instead of dioptric lenses. After these 2 weeks with plano lenses, they changed to dioptric lenses and continued the training.

The training was done by each child at home following a protocol. An optometric examination was performed every second week to insure high compliance. If a subject showed a hypermetropia, plus lenses were prescribed after the first or second optometric examination, for proper progression of the accommodative facility training. The training continued until the subjects reported that the symptoms were gone.

## RESULTS

### Paper I

In all 38 children, the symptoms, such as headache and asthenopia, gradually decreased and finally disappeared during the training period. The length of the training period varied from 3 weeks to 25 weeks, with the training period being less than 8 weeks for the majority of children. A high compliance were demand. Therefore, the children as well as their parents were given wide instructions before the onset of the treatment and the compliance were monitored after every examination. As far as could be determined the children were in compliance with the prescribed treatment.

The mean for NRA as well as that for PRA increased during treatment. However, for both NRA and PRA, the post-training results were significantly lower than were the data on the controls. In other words, there was a statistically significant increase in both NRA ( $P<0.0001$ ) and PRA ( $P<0.0001$ ) during the training period, although both the parameters PRA and NRA were significantly lower than the results obtained among the controls (viz.  $P=0.024$  for NRA and  $P<0.0001$  for PRA).

A follow-up examination was performed 2 years after the final examination. None of the children had any dioptric training during the time that elapsed from the conclusion of training to the follow-up examination. Both NRA and PRA were almost the same at the conclusion of training as at the follow-up examination and none of the children had regained any symptoms.

### Paper II

In the sham group, flipper treatment was divided into three periods, with an initial 2 weeks of accommodative facility training using a plano lens flipper as the sham treatment. This sham period had no effect on the symptoms (i.e., headaches, asthenopia, blurred vision) of the patients. In the following 2 weeks, a  $\pm 2.00$  D flip lens set was used and by the end of this period, some symptoms

had vanished. The period of accommodative facility training was extended until all of the patients were free from symptoms. This extended period, starting in the fifth week of training, varied in length with each case.

There was a decrease in both mean NRA and mean PRA during the first period of training while the patients used plano lenses. This decrease was recovered in some of the patients during the next 2 weeks when a  $\pm 2.00$  D flipper was used. The traditional treatment group who started their training with a  $\pm 2.00$  D flip lens showed an increase in their mean relative accommodation at each examination. Their symptoms vanished by the end of the training period.

The results show that the first weeks of dioptric training in the sham group as well as the traditional group showed an effect of the dioptric training, and in all subjects, the training had an effect for the whole of the training period. In concordance with this is the fact that the plano lens flipper did not have any positive effect on either mean NRA or mean PRA in any patient in the sham group. It is, however, difficult to explain why the PRA value actually decreased during the sham period for all the patients in the sham group. If there are any placebo effects, we should in fact expect an increase instead of a decrease in the relative accommodation values during the sham period. Despite some individual variations in the results, our data show a significant increase in both mean NRA and mean PRA in both the sham group and the non-sham study group during the dioptric training.

## DISCUSSION

The patients included in this study were selected from among children with problems at school related to near work. It was found that all of the selected patients had reduced relative accommodation and the majority of them had a slow accommodative facility. None of the patients could be classified as having the syndrome called convergence and accommodative insufficiency, as described by Von Noorden *et al.* (1973). The studies were performed to investigate the possibility of increasing or improving accommodative function as being the probable main problem of these patients. We therefore tried to accomplish three goals: firstly, to quantitatively examine the effect of accommodative facility training on relative accommodation; secondly, to determine whether symptoms (headache, blur, asthenopia) disappeared with increased accommodative facility; and thirdly, to establish whether the dioptric training had any long-term effects.

Accommodative insufficiency and accommodative facility training have been discussed in the optometric literature mainly during the past few decades (Hennessey *et al.*, 1984; Daum, 1983; Cooper *et al.*, 1983; Cooper *et al.*, 1987; Rouse, 1987; Chrousos *et al.*, 1988; Russel & Wick, 1993), predominantly with regard to pre-presbyopic patients (Zellers *et al.*, 1984; Cooper *et al.*, 1987; Russel & Wick, 1993). The close relationship between accommodative deficiency and related visual symptoms, such as blurred vision, asthenopia, loss of concentration, and avoidance of near activity, has been pointed out. Among the findings listed by Hoffman & Rouse (1980), as indicative of accommodative difficulties when associated with symptoms, we focused on two items: a NRA and PRA of  $<\pm 1.75$  D, and a  $\pm 2.00$  D flipper test result, measured monocularly and binocularly, of  $<12$  cpm.

The proposed relationship between restricted relative accommodation and symptoms was in concordance with our findings. The results of these studies to some degree support the idea that a PRA and a NRA of  $<\pm 1.75$  D (Morgan, 1944; Hennessey *et al.*, 1984) are related to the presence of symptoms (i.e.,

headache, blurred vision, asthenopia, loss of concentration, and avoidance of near work).

Our studies indicate that accommodative facility training can increase relative accommodation, both positive and negative, in selected patients, as well as relieve them of their symptoms. The studies also clearly indicate that there is a long-term effect of accommodative facility training using a dioptric flip lens technique. However, it is not clear from our studies whether the relief of symptoms was linked to an increase in relative accommodation or to an improvement of the accommodative facility, or both. We also do not know whether further accommodative training would have further increased the accommodative function.

Since the question has been posed whether it is the actual use of dioptric training that causes an increase in relative accommodation or whether unspecific training and caring can lead to such increase we studied the effect of sham treatment in seven patients given such treatment before the dioptric training. The findings clearly indicated that short-term sham treatment, if anything, had a negative effect on relative accommodation and no observable effect on symptoms.

The lack of a positive effect of the sham treatment with plano lenses strongly suggests that the therapeutic effect of dioptric treatment of the accommodative facility is linked to the effect of the  $\pm 2.00$  D flip lenses. The focus of this study was to examine changes in relative accommodation in relation to treatment. The fact that the effect on the relative accommodation of 2 weeks of dioptric training following the sham treatment was as marked in this group of patients as it was in the traditional training group starting directly with dioptric training further links the positive effect on relative accommodation to the use of the  $\pm 2.00$  D flip lenses.

Information about the natural history of accommodative dysfunction in children is lacking, and we do not know whether relative accommodation spontaneously improves with age. However, even though the effect of maturation cannot be excluded from the present study design, our clinical

experience is that accommodative infacility lasts for years. The dioptric training had a positive effect on both mean PRA and mean NRA and the symptoms, and offers the possibility of at least shortening the period of symptoms and withdrawal from near work at school at a stage in schooling that is academically important.

The result, in terms of the dioptric treatment, in this study is in agreement with results reported previously in the literature (Daum, 1983; Cooper *et al.*, 1987; Siderov, 1990; Russel & Wick, 1993; Sterner *et al.*, 1999), although accommodative insufficiency has been more commonly reported in pre-presbyopic individuals than in school children (Hennessey *et al.*, 1984; Cooper *et al.*, 1987; Russel & Wick, 1993; Scheiman *et al.*, 1996).

The result further raises the question whether the facility training method is a useful method for other aspects of the ophthalmological practice, such as in diagnosing and training an accommodative impairment among visually handicapped children. An accommodative impairment can in some cases be hidden in an incorrect interpretation of eye disease and associated symptoms. The contact person of the child may conclude that the child's difficulties in performing near work are the result of eye disease instead of being due to an accommodative impairment.



## CONCLUSIONS

In conclusion, this study has characterized a group of children with impaired relative accommodation. They were relieved of symptoms and as a result of dioptric training, they improved both their NRA and their PRA. In order to optimize the training and the diopter value of the lenses, the training intensity and spacing of training sessions over a considerable period still need further evaluation. It is also of utmost importance for a direct and successful treatment that children with accommodative dysfunction be properly diagnosed and that other ophthalmological problems be excluded.



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