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When Does Blur Matter? A Narrative Review and Commentary

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ABSTRACT

Blur is the subjective awareness that the edges of a high contrast image are indistinct. The concept of blur is fundamental to the understanding of vision, accommodation, refractive error, concomitant strabismus, and asthenopia. It is easy for clinicians to believe that blur always needs to be avoided or resolved, or that everyone responds to blur similarly. This narrative review outlines the literature on blur and the accommodation to resolve it, and relates it to current clinical practice. Laboratory studies have traditionally been highly controlled, using expert observers, but more recent research using naïve participants suggests that variability and tolerance of blur are common and more widespread than often thought, especially in children and clinical groups. Objective and subjective responses can differ widely, and it cannot be assumed that because we expect accommodation to have occurred, that it always has. A deeper understanding of the role of blur and objective accommodation in vision, refractive error and strabismus may help us understand the variability that exists in clinical practice. We may use blur to help investigation and treatment but also be relaxed about what is normal. Many patients are led to believe that they should always achieve constant clear vision, when this is unrealistic. Although pathological blur must be identified and treated, normal everyday blur may become medicalized into “a problem” by well-meaning professionals.

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Introduction

A common question we ask our patients is “do you notice blur”? Depending on the answer, our clinical investigation will go down a particular route toward our best diagnosis. But are we asking enough, or the right, questions, and are we fully aware of the implications of the answers? This overview will consider the role of blur in accommodation, strabismus, and orthoptic practice in relation to the literature.

Blur is noticed when there is a subjective awareness that the edges of a high contrast image are indistinct. In clinical practice, blur is generally caused by optical causes or defects of the ocular media. Everyday blur is so common it is rarely discussed. Everything in front or behind the fixation plane will be blurred (and double), but this is rarely noticed. Blur is all around us, and accommodation to resolve it is largely an automatic and unconscious response. It only becomes a concept, or a “problem” when we have been shown that clearer vision is possible and desirable, and especially if we then struggle to achieve it. The only people who regularly think about blur are eyecare professionals, people who forget their glasses, developing presbyopes, and a very few of our patients.

First-time myopes only realize how blurred things are once they have been shown how much better it can be when corrected. Children often have to be helped to understand what the word “blurred” means even if their vision is very poor. So how much importance should we give to blur?

This narrative review will mainly consider central blur of the target of fixation and the role of accommodative blur and manipulations of refractive error in binocularity and strabismus. It will not consider the newer and growing literature and controversies around the role of blur in myopia development and treatment, particularly on the role of peripheral blur (where the foveal image is clear, but there is optical, specifically hyperopic, blur in the image periphery). These are beyond the scope of this paper, but introductory reviews can be found by Atchinson and Rosen,[1] Cooper,[2] and Cheng et al.[3,4]

Some science

Blur detection has been the subject of vision science literature for decades. Earlier studies were frequently highly controlled laboratory research, using knowledgeable participants such as optometry staff and vision scientists primed to actively look for blur. More recent work, however, has explored responses to blur in infants, children, and naïve participants, often with very different results.

Signals to accommodation

Blur is traditionally thought to be the main stimulus to accommodation, while disparity drives vergence.[5] Blur is a “sufficient” stimulus to accommodation, which means that when presented as an isolated cue it can drive a large proportion of the accommodation required to clear the image, although it is less efficient away from the very central visual field.[6] Reduced blur detection in the periphery is a combination of intrinsic (neural and anatomical) factors such as large cortical receptive fields, and decreased blur sensitivity.[7] Despite blur being “sufficient,” blur nearly always occurs at the same time as other cues to nearness such as disparity and monocular proximal cues (looming, motion parallax, overlay of contours, learned size etc.). Individually, each of these cues can drive a significant proportion of the total response required, and if added, would produce much more than 100% of the required response, so in practice they must be weighted.

Recent studies are highlighting complexities, flexibility, and individual differences in the incoming balance of these different cues, which can change with variations in lighting, binocularity, motion, and other factors during everyday binocular vision.[8–12] For example, a binocular looming image presents a very different stimulus mix than a monocular, stationary one.

Blur is an inefficient cue. “In isolation from other cues, blur may provide only a coarse cue to depth and add limited depth information when present in natural scenes with complex distributions of blur and multiple depth cues.”[13] Bernal-Molina et al. suggest that “the main purpose of accommodation is not to maximize retinal image quality but to form one that is good enough.”[14]

Held et al. suggest that “Blur could in principle fill in the parts of visual space where disparity is imprecise” and that blur and disparity are complementary cues to depth.[15] Mather suggests that blur and stereo operate in complementary fashion in depth perception, with stereopsis covering near distances and blur relatively further targets.[16]

Cross-links between the vergence and accommodation systems mean that blur can drive vergence and vergence can drive accommodation, expressed clinically by the AC/A (accommodative vergence to accommodation) and CA/C (convergence accommodation to convergence) ratios.

Many studies now suggest that disparity drives most accommodation in conditions where multiple cues are available.[8,9,17–19] So binocularity is a major aid to accommodation, while blur is not a particularly strong aid to vergence,[20] despite traditional strabismus literature suggesting otherwise.

Depth of focus

Depth of focus is typically around ±0.3 to 0.5D either side of fixation and has long been shown to vary significantly with pupil size and light levels.[21,22] This means that even at the lower value of ±0.3D, an image at 50 cm would be seen as clear anywhere between 43 cm and 60 cm from the eyes and would drive no further accommodation. These physiological accommodative leads and lags are not noticed subjectively. In comparison, disparity cues, measured in seconds of arc, can detect depth differences in *millimeters*, not centimeters, at the same distance, so are a much more precise cue.

Tolerance and sensitivity to blur

It is very tempting to assume that just because blur *can* fine-tune focus to within an individual's depth of focus, that it *does*. More recent research suggests that this assumption can often be wrong

Laboratory studies using expert observers experienced in vision experiments may produce excessive responses,[23] while accommodative lag is typical in clinical and general populations. Naturalistic or impoverished stimuli and tasks, and minimal instructions, generally reduce accommodative responses.[8] Accommodation and vergence also involve a certain element of "effort to see"[24] and mental processing demands,[25,26] so differences in task, instructions, attention, or cognitive load may explain why children and naïve observers behave differently.

Atchison et al. studied "noticeable, troublesome and objectionable" blur.[27] This work suggests that blur may not be noticed until it is looked for, or be noticed but not troublesome, or troublesome but not debilitating. Blur is less bothersome in a row of text or with larger optotypes than a single small optotype. Bothersome blur thresholds are much worse than those for blur detection[28] and presbyopes are less sensitive to blur than younger adults. Blur tolerance is also related to personality.[29] We are all familiar with one patient rarely wearing their glasses, while another with a lesser prescription is unable to function without them. Blur particularly affects night-time driving[30] and may exaggerate the effect of night myopia.[31] The blur perception of amblyopia is not the same as optical blur and thresholds can differ.[32]

Horwood and Riddell have been researching accommodation for many years, often reporting infant, child, and patient responses in comparison to those of typical adults. Because young and clinical participants are less instructible, they have always used adult control participants naïve to the visual tasks, and who are not instructed to do anything in particular beyond "look at the picture (a clown face), which has fine detail available if they choose to resolve it. In such naturalistic conditions, typical, asymptomatic, co-operative young adults rarely accommodate well to blur cues alone. Using a detailed target, but fixing monocularly, with proximal and looming cues minimized, accommodation is typically poor, with a mean response gain of less than 50% of the target demand[8,9,33] i.e. less than 1.50D response to a 3.00D demand. Even to their richest target with maximum accommodative stimuli available, although most people accommodate and converge broadly in parallel, others are happy to *not* accommodate as they converge. *Mean* lag to this naturalistic target is around 0.5D, but this mean does not reflect the variability. Many asymptomatic typical young adults do not accommodate well, or linearly with convergence, or even consistently within the same visit (Figure 1). Although the participants could accommodate well, they either did not attend to, or make appropriate efforts to respond to near cues, especially under monocular conditions. Tolerance or inattention to blur well outside depth of focus is common, and accommodation and convergence are often not as tightly linked as might be expected. Accommodation is naturally variable.[34]

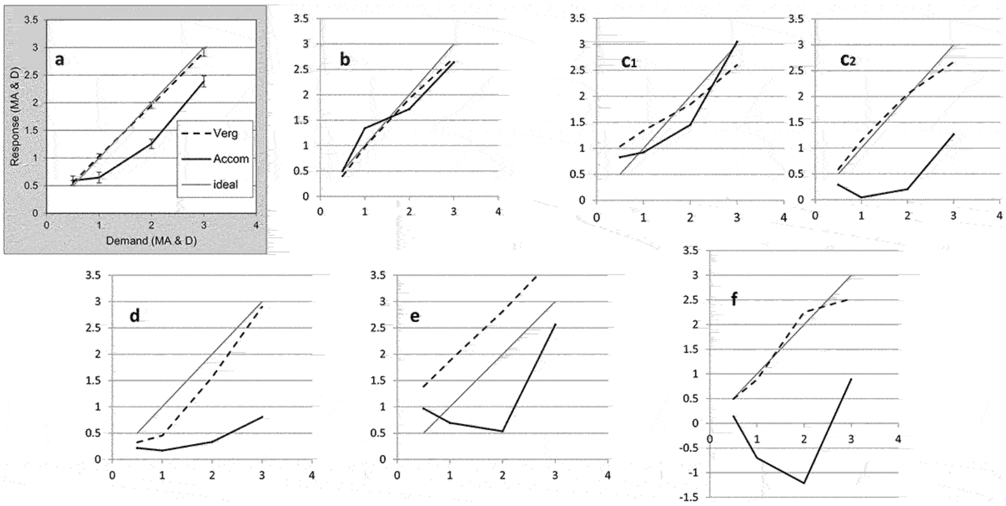

Figure 1. Illustrations of simultaneous accommodation and convergence responses within a group of typical, asymptomatic young adults fixating a naturalistic, binocular detailed target moving between 0.5 and 3.00D demand. Vergence (red lines) plotted in meter angles (MA) so responses can be compared with accommodation in D (blue lines) on the same chart. (a) Group mean responses (with standard error bars) of the group. (b)–(f): individual responses. (b) "good" response (c) two recordings to the same target a few minutes apart (c1 and c2) showing intra-participant variability (d) good convergence, poor accommodation (e) "all or nothing" response which only accommodates to the nearest target (f) poor "all or nothing" response in a mildly hyperopic participant ("minus" response when accommodation relaxed) despite fairly linear convergence.

Accommodative lag

Accommodative lag varies with age and is greater in children[35–38] and especially children with Down syndrome who are less sensitive to blur,[39,40] and those with cerebral palsy[41] or on the autism spectrum.[42]

Blurred text may result in additional accommodative lag[43] and possible asthenopic symptoms, but many typical children seem happy to read with significant lag outside depth of focus.[44] Due to cognitive limitations, early readers' print is typically very large, so even very blurred letters and words can still be identified. Therefore, we cannot assume that early readers habitually accommodate as much as we think they do or that mildly blurred vision hinders literacy acquisition. Accommodation on sustained reading may be very variable[45,46]

Refractive error is also influential. Some progressing myopes have more lag than others,[47] and poor accommodation in young adults on sustained reading may predict myopia development.[46] Most uncorrected hyperopes have significantly more lag than emmetropes.[47,48] Blurred text does not stimulate as much accommodation or convergence in adults – so it is possible that hyperopic lag for close work reinforces itself.[43] Presbyopes suffer gradual decline in accommodation[49] so are forced to operate with higher levels of blur for any distance that is not optically corrected. People can be taught to accommodate or respond to blur more precisely, with practice and careful and consistent training and instructions[50,51]: but the opposite is also true and many people can teach themselves to voluntarily relax accommodation, e.g. an artist "blurring out" to assess an overall effect.

Blur adaptation

Behavioral responses and visual acuity can improve under conditions of prolonged blur due to blur adaptation,[52–54] which re-calibrates *the perception of blur* (to the sharper of the two eyes' images if they differ).[55] This "getting better at functioning with blur" may be why uncorrected refractive error in children may not hinder their play, and why people trying non-evidence-based alternative therapies for refractive error, such as the Bates Method,[56] claim their vision improves when they discard their glasses. There is evidence to suggest that accommodation becomes more variable after blur adaptation.[57]

Development of accommodation

Infants are born with high levels of optical and neural blur, and poor visual acuity,[58] but by three months of age they can accommodate at approaching adult-like levels when the target is binocular,[9,59–61] but not monocular.[18] This is at an age when visual acuity is still very low, so it is very possible that the onset of binocularity gives a new additional drive to the onset of more mature accommodation as much as improvement in visual acuity. Most young children are mildly hyperopic. Roberts et al. found that, up to 10 years of age, children can have lower levels of blur detection and increased microfluctuations which were associated with more hyperopia. They ascribed this to higher accommodative demand of the hyperopia,[62] but it may also relate to attention. Accommodation in children is likely to be naturally fluid and adaptive with time.

Asymmetrical output

Uniocular blur has been found to be dissociative in accommodative esotropia,[63] so symmetrical input is important, but what about output?

Accommodation is traditionally thought to be symmetrical in each eye, driven by demand from the better eye. In most typical adults and in experimental situations, this is true (although experimentally, brief periods of aniso-accommodation may also be taking place).[64] In the developmental case of anisometropic amblyopia, however, Toor et al.[65] found it could sometimes be asymmetrical or even paradoxical with one eye accommodating, while the other "anti-accommodated" at the same time. Defective accommodation has been reported in amblyopia before,[66–68] but until simultaneous accommodation measurements in each eye were possible, this asymmetry was probably missed because most equipment only measures accommodation in one eye at a time, even if the target is presented binocularly. This rare finding in a clinical group raises many interesting questions about the neural control of accommodation.

AC/A issues – the blur drive to convergence

Blur and the other visual cues contribute to a calculation of target distance. Blur could drive convergence to a target directly via the AC/A linkage, but it seems more likely that it contributes to a global calculation of target distance, which drives both responses. This is very difficult to explore experimentally in naturalistic settings, so it may be more appropriate to explore by modeling.[69] Regardless of the mechanism, we know that manipulating blur can change convergence. The concept of the AC/A ratio underpins much of orthoptics and concomitant strabismus theory, but it fails to answer as many questions as it solves.

The linkage between accommodation and vergence appears to be learned in early infancy and is fairly stable until presbyopia sets in. Although most people converge and accommodate in broadly proportional amounts, there is significant flexibility and variability in naturalistic settings. If manipulating blur with lenses changes the angle significantly, the AC/A ratio is probably high. If manipulating blur does not change the angle, then the AC/A ratio may be truly low, with accommodation contributing to little blur-driven convergence. Alternatively, the accommodation we think we have induced may not have occurred, so the AC/A ratio could be normal, just not being used. It is also possible that accommodation and convergence may be more independent or weakly linked systems, responding individually and separately to the calculation of target distance.

Clinicians are used to individual differences and clinical inconsistencies. Horwood and Riddell have suggested that there can be "blur people" or "disparity people," with different characteristic styles of responses to near cues.[70] Blur people rely more heavily on blur cues than disparity to drive their vergence and accommodation, possibly due to a primary defect of binocularity. This may predispose them to accommodative deviations and abnormal AC/A ratios as they strive for clarity more than most children.

They appear more unusual in the typical population, but strabismus practitioners may see more "blur people," so we may have developed an inflated idea of the importance of blur in the non-strabismic world.

Most people use disparity as their main cue to near responses, and blur is a weak cue. For these, the CA/C linkage is primary (they "converge to accommodate"), and the AC/A linkage and lens manipulations will have less importance, whatever their numerical value measured by tests which try to control for everything else. We need to be aware that a disparity bias may mean that changing disparity input, with prisms, occlusion, or surgery, may produce accommodative blur because the vergence demand has changed.

Blur in strabismus

If disparity detection has been faulty from early childhood, e.g. in infantile esotropia, it is likely that the accommodative drive will rely on remaining blur or proximal cues.[9] However, it cannot be assumed that all strabismic children have poor accommodation. In fact, their monocular accommodation may even be better than it is in binocular children because it does not depend as much on binocularity.

If a strabismus is acquired *beyond* infancy, when idiosyncratic cue weightings may have already developed,[9] loss of binocularity is likely to reduce the disparity drive to accommodation around the onset of the strabismus, and so may cause greater lag.

Horwood and Riddell[70] have speculated that different groups of hyperopic children behave differently, depending on their response to blur and the strength of their desire for binocular single vision and stereopsis. This is also supported by Hasebe et al.[71] A hyperopic child with a strong AC/A linkage is presented with a dilemma – straight eyes but blurred vision or clear vision and esotropia with diplopia. Those fortunate enough to develop relatively independent vergence and accommodation systems (which could be the basis of good "relative accommodation/vergence ranges") may manage to keep straight *and* clear, but most "choose" one path – accommodative esotropia, or blur and possible ametropic amblyopia.

Strabismic children rarely emmetropise like their non-strabismic peers.[72] Ingram speculated that children destined to be strabismic did not recognize blurred VA and didn't emmetropise because of poor primary binocularity,[73] so the defective binocularity was the initial problem, not the hyperopia. Poor binocularity could well cause poor emmetropisation, so the hyperopic infant stays hyperopic with a high risk of accommodative esotropia, when fully binocular children are more likely to emmetropise.

Blur and literacy

It seems obvious that a child with more blurred vision would struggle at school, and there are many publications linking hyperopia or poor accommodation to impaired literacy.[74–79] What is less clear-cut is whether the blur is *causal* to the poor attainment. It is still feasible that children destined to have poor attainment due to other developmental, environmental, or social disadvantages do not emmetropise out of early hyperopia or accommodate as accurately due to poorer attention. Although the effects on visual outcomes of early correction of hyperopia have been studied (with some inconclusive results)[80] more, very carefully controlled and complex research, considering cognitive, attention, environmental, social, and visual factors, is still needed to untangle causal relationships.

Clinical implications

In the history

Blur as a symptom is rarely spontaneously noticed by children or the pre-presbyopic general population, and if it is, the main questions are probably "why," and "who alerted them to it"? What is most commonly noticed are the *effects* of blur – and an inability to perform a task. It is important to sort out whether they have noticed, or been alerted to, blur that others would consider normal, or if it is truly outside normal limits. A first subjective refraction may be the first time the concept of blur has ever been introduced, but it can quickly turn a naïve observer into an "expert" and introduce the concept that all blur is abnormal.

As professionals, we need to be aware of blur, and use it for our investigations and treatment, but also be relatively relaxed about it. Blur and moderate accommodative lag are NOT always abnormal, especially in our patients. Most people do not accommodate all the time or work for clear vision every minute of the day. Many of our patients are the people who are least likely to have accurate accommodation – strabismic, with refractive errors, amblyopia, developmentally challenged, young, with poor attention or motivation. We should not assume that just because they "should" accommodate or experience blur, that they have done so, or actually need to.

We have all seen patients where a well-meaning parent, teacher, or optometrist have alerted a child to blur as "a problem," a problem which did not exist before they were asked to think about whether they noticed it. A web search of "blurry vision" brings up multiple frightening diseases. Searching on "is blurry vision normal?" suggests strongly that it is *not*, despite a large body of literature to suggest that tolerance of blur is a normal part of life. By the time patients get to us, often a mild observation has become a medicalized problem. This needs careful and informed explanation. Some of the questions in Table 1 might help.

Table 1. Specific history questions relating to tolerance and expectations of blur (Table view)

Did you think about, or notice blur before anyone asked you about it?
Did it trouble you before that visit?
Does your blur trouble you now?
How often do you think about it?
Does your blur ever stop you doing something you love (especially small screens!)?
It may be blurred if you try to get it clear, but if you are absorbed in something interesting, does it stop you?
If it goes blurry can you usually get it clear?
If you can't, what do you do?
Does it stop you doing your work or school work?
If you have glasses, do you always wear them, keep them very clean, sometimes forget to get an eye check every year?

Spectacle correction

We cannot assume children initially wear glasses to see better. Compliance with glasses can be more about comfort and social acceptance rather than better vision at first.[81,82] It is a common convention to under-correct hyperopia in non-strabismic children.[83] Hyperopia is often first detected at a first eye test at 3–5 years of age, and undercorrections are common in non-strabismic children, partly for residual blur to encourage further emmetropisation and because it is assumed they will "make up the difference." This may be the case, but research shows that many uncorrected, or under-corrected, hyperopic children do not do, or habitually keep up, this additional accommodation.[48,84]

Horwood and Riddell[84] found that although hypermetropic children may do the appropriate extra accommodation to go from distance to near (e.g. 3.00D more), they maintained a consistent level of under-accommodation at all distances, which is related to the size of their undercorrection – doing "just enough" as suggested by Bernal-Molina.[14] If hyperopic children of approximately 4 years of of age had the capacity to emmetropise when younger, why have they not done so already? Once the hyperopia is fully corrected, studies did not find the accommodation different from typical children.[85] Are our undercorrections just leaving children to manage with blurred vision and blur adaptation? It seems likely that an undercorrection will only help a child who is proven to consistently accommodate over the under-correction and still be emmetropising. As discussed earlier, these are usually children with normal binocular vision. The simple measure of performing a dynamic retinoscopy to habitual binocular task such as a smartphone will help differentiate children for whom an undercorrection is leaving them with excessive accommodative lag, from those who accommodate well.

In orthoptic tests

We are used to using "accommodative targets," and assuming the target is kept clear throughout our test, despite using occlusion which may take away the disparity that is most children's main cue to accommodation. This is often carried out rapidly by experienced clinicians. It is particularly important that clarity is achieved *between each swap of the occluder* when measuring any clinical AC/A ratio. This is surprisingly difficult – try it through a minus lens! We should also bear in mind that depth of focus means that accommodation will probably be around 0.50D less than we think it is, so our "stimulus" AC/A ratio will nearly always underestimate the true "response" ratio (where vergence change is calculated in relation to actual, not assumed, accommodation).

When testing typical young adults for a large trial,[86,87] Horwood et al. found that a surprising number were totally unable to subjectively overcome −3.00D lenses for distance or +3.00D lenses for near, especially monocularly, so we cannot assume that just because we have put up a lens, everybody can voluntarily manipulate accommodation to compensate. The solution is to use a weaker lens, but then the inaccuracy induced by higher proportion of depth of focus within the response, will be greater. In the same study, they were unable to collect meaningful data on the "blur point" when testing the prism fusion range, because so few noticed one. This may be because they genuinely did not experience blur (a good relative accommodation range) or were just tolerant of the mild blur and did not notice it.

Assessment of accommodation

Accommodation is particularly affected by instruction-set,[51,86] so it is important to keep instructions clear, precise, and consistent between every tester and every visit. Accommodation is usually assessed in terms of maximum achievable (near point, amplitude (how strong a lens can be overcome)) or response facility (cycles per minute using flipper lenses or between near/distance). There may be a large difference between these maximum responses and habitual, sustained behavior, but we rarely assess this beyond noting reported symptoms. As we have seen, tolerable lag is very variable. There is equipment that can measure sustained responses e.g. open field binocular (PowerRefractors) or monocular (e.g. Grand Seiko) autorefractors, but they are rarely available clinically. The best clinical methods are probably a Nott[88] or Bell[89] retinoscopy, performed while a child carried out a habitual task over a few minutes, e.g. the size print they are required to read at school or their favorite app on a smartphone. When objective and subjective methods are compared, they may correlate poorly[90] because many people are poor at noticing or reporting subtle blur, while objective measures such as autorefraction will detect small deficits. Accommodation assessed by dynamic retinoscopy when watching a smartphone social media feed may differ dramatically from a formal subjective blur point test in anxious adolescents, or using text, so all should be done. Formal testing using professional equipment or using text with a dyslexic child may dramatically reduce responses. Using naturalistic targets to assess accommodation, involving presentation of multiple clues, e.g. a binocular, looming target, is likely to be more applicable in clinical settings than highly controlled methods, such as monocular stimuli or using Badal systems, which can present blur cues in isolation.

Amblyopia

The higher accommodative lag,[66,67,91] and in anisometropia, even asymmetrical responses, raises the interesting question of the value of accommodative tasks during amblyopia treatment. Evidence is weak that adding close work to amblyopia therapy improved outcomes[92,93] but should these studies have first corrected any lag with lenses to show the children what optimum vision looks like (because we know amblyopes may not do the last little bit of accommodation), or should the research have used tinier, challenging threshold targets to stimulate accommodation specifically?

Accommodative esotropia

Hyperopic children with fully accommodative esotropia may have been forced into their strabismus by the real-life dilemma between poor vision and straight eyes or strabismus and clear vision. Even so, they rarely complain of blur and may have to be explicitly taught to use it during therapy to discard or reduce glasses. Blur might be so familiar that they do not explicitly describe it without glasses or pay attention to it.

What are we doing when we try to reduce or discard hyperopic spectacles or bifocals during orthoptic treatment?[94,95] The first stage is often to ask children to purposely relax their accommodation while recognizing joining of diplopia. The end stage of the treatment is good controlled binocular acuity – controlling but also accommodating. But do we objectively check this accommodation? Are we sure that a short-term ability to accommodate without becoming esotropic in the clinic can be maintained all day? Or are we just encouraging them to learn to function with adaptation to higher levels of blur? And could this impact attention or education?

Distance exotropia

In intermittent exotropia, we concentrate on features of control and use lenses extensively in investigation and treatment, but perhaps we should ask more questions about these patients' experience of blur. For overviews, see Kushner,[96,97] Horwood.[98]

Horwood and Riddell found that accommodation drops dramatically when control is lost.[99,100] If clinical patients are questioned more closely, many notice *blur*, not diplopia, when control is lost. If accommodation reduces on decompensation then it will cause a double disadvantage – loss of binocularity and stereopsis, as well as blurred vision during close work. This may be the strongest justification for surgery.

Minus lens therapy is an established treatment for intermittent exotropia and can be useful to prevent or delay surgery,[101,102] even if long-term results post treatment are poorer, with the added concern about exacerbating myopia development.[102,103] But even if the control improves in the clinic with minus lenses, are we sure they keep up the additional accommodation all day? A child *may* do so, with a good effect on the deviation. Or they might only accommodate when they need to, for detailed close work. This will give some improvement, but more task-dependent variability in the control, and possibly extended periods of blurred vision. Or they may just learn to tolerate the blur (because they are already good at it)[104,105] and so the lenses do not affect the deviation at all. This may explain the very variable responses to lenses that occur clinically. Do we ask enough questions?

Dynamic retinoscopy to a habitual target when considering prescribing minus lenses might help sort out a child's natural response to the intervention and help decision-making.

The therapist effect

Orthoptists and vision therapists are taught to manipulate blur and disparity to improve control of deviations and relieve symptoms.[106] We know exercises can work, but *how* they work is less clear. Studies have shown that accommodative facility can improve with training,[107,108] but the effect of an enthusiastic therapist, and placebo and Hawthorne effects are rarely studied. Horwood et al. attempted to separate treatment, practice, encouragement, and placebo effects in a trial of eight different treatment regimes on binocular vision variables in typical young adults.[86,87] They found that many of the participants had very poor blur awareness or voluntary accommodation control (unable to clear lenses or notice blur points). Many accommodative parameters, especially monocular accommodative facility, showed large practice and therapist effects, but little response to exercises specifically targeting blur awareness.

Accommodative anomalies

Patients with accommodative anomalies, such as accommodative spasm, insufficiency, or inertia, are known to have a strong association to psychological stress,[109,110] and can be challenging to manage. Many of these patients do not have the usual linear relationship between accommodation and convergence and can often do one without the other. This behavior is also common in very young infants, so it could be a retained primary ability to dissociate the two systems or a learned behavior to avoid stressful situations, such as reading in dyslexia. Even momentary accommodation or normal responses can confirm the integrity of the accommodation and convergence pathways.

A common theme for many of these patients is an initial mild problem, triggered by life stresses or minor head trauma, which has worsened over years of eye professionals trying multiple unsuccessful treatments. Excessive thinking about consciously achieving clarity appears to move what is usually an automatic system into the conscious domain, which often makes things worse. If somebody asked you to accommodate voluntarily, how would you do it?

It is really important to differentiate between the normal blur that we all experience at times that has become medicalized and turned into a problem, from the much rarer pathological blur due to a medical cause, e.g. drug-related, trauma, neurological pathology.

Many patients with apparent accommodative anomalies have been led to believe that normal people see clearly all the time, so expect constant perfect clarity, which does not exist. These patients are very similar to those with other somatic symptoms (headache, stomachache etc.) due to psychological stress. The approach used by the Infant Vision Laboratory at the University of Reading, UK, is to explain how research shows that most people are happy to tolerate large levels of blur from time to time and normal people do *not* always have clear vision and rarely think about it. Even momentary objective evidence that accommodation can be achieved is enough to confirm the integrity of the neural accommodation pathway. An evidence-based psychological approach is then used to give patients insight into the mechanism of their symptoms. By explanation, confident reassurance, simple psychological informal or formal strategies,[111] and (very occasionally) simple orthoptic exercises, some excellent results can be achieved. The main strategy is to reassure patients that blur is part of everyone's life and that they *can* accommodate, even if they have got out of the habit of doing so.

Conclusions

Blur is part of life for most everyday tasks and most people. Accommodation is usually an unconscious and automatic act, which is probably best left that way if possible. It works in the background to help optimize visual acuity and binocular vision. If blur is an intrinsic part of how a person controls their binocular vision, it may be a useful signal we may be able to use to manipulate a troublesome deviation or symptoms. We must, however, keep in mind that there are many situations where blur is normal. Professionals need to be aware of the properties of blur detection and accommodation but should avoid implying to their patients that blur is always bad.

Disclosure statement

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