ABSTRACT
When observing infant retinoscopic responses, it may be advisable to regard near retinoscopy as an infant’s relaxed state because of the order of visual development. The infant sustains a meaningful visual contact first at near and then moves outward. This essay is based on Gesell’s utilization of an ordered organization of development from the skeletal, to the visceral, and finally to the cortical stage. He compared these functions in vision to visual reaching, grasping and manipulation. This is the history of how infant retinoscopy developed as an extension of dynamic retinoscopy.

This paper introduces a model for defining the differences in retinoscopy reflexes as they relate to Gesell’s three developmental categories. In so doing, it helps the retinoscopist focus on the different aspects of the reflex as a way to help understand an individual’s visual performance. These retinoscopy observations raise a question about what with and against motion indicate when examining infants. This is based on the recognition that relative convergence and relative accommodation are not equal to the related changes in physical optics. Relative accommodation and convergence are evident whenever an individual visually localizes a perceived distance which is different than the physical distance. As an example, when an individual attends to a base-out (closer) or base-in (farther) projection of a stereopsis view, the perceived distance is different than the physical presentation. Relative accommodation and accommodation yield different qualities and motion of the reflex.

KEY WORDS
accommodation, dynamic retinoscopy, Gesell, infant, reflex quality, relative accommodation, retinoscopy, retinoscopy reflex, visual grasp, visual manipulation, visual reach

INTRODUCTION
After a hiatus of almost 30 years the optometric profession has a renewed interest in infant vision examinations. This article concentrates on retinoscopy which is the hallmark procedure used by the profession when evaluating infant vision. Retinoscopy with infants evolved from an optometric developed procedure, dynamic retinoscopy. Retinoscopy with infants is important because much of the information gleaned from infants is limited to observation and objective testing.

In addition to a review of related history, the major thrust of this article is a presentation of a model to expand one’s view and interpretation of infant retinoscopy findings related to vision development. The organization used in the paper is based upon Gesell’s view of child development. Gesell recognized that in either child and/or visual development, it is important to understand the principal aspects of the process. He utilized an organization and order of development which consisted of skeletal, visceral, and cortical functions. During the developmental process, meaningful visual contact with the environment starts at near (6–9 inches) and slowly extends further into space. Gesell envisioned the visual process similar to the development of hand use, one of reaching out and localizing (skeletal), grasping and contact (visceral), and finally emancipating and intellectually converting (cortical). He was the first to recognize that the foundation for visual development...
was visual motor and that general motor development precedes and activates sensory development.

Gesell\textsuperscript{2} used a hierarchy based on the order of development. He also related specific aspects of observed behavior to these hierarchical categories. In his interpretation of development, Gesell recognized that the skeletal function was primary. He viewed and considered motor function and control by studying single film frames from the many movie films they produced. Secondly, he considered visceral function highlighting the internal processes of feeling, the gut response and emotional response. These describe coming into personal contact through physical experiences and includes responses related to visual attention and emotions. Finally, he considered cortical function related to the neurological processes that include mental processing. His basic model was a motor-neural model which concentrated on the development of physical action as well as supporting neurological control of the action. He was criticized at times for seemingly ignoring one aspect of the visceral development, a Freudian view of emotions.

In this article, I utilize Gesell’s three primary developmental components to describe aspects and observations made with retinoscopy. I have highlighted how different qualities of the retinoscopy reflex are related to the multidimensional view of visual function described by Gesell (skeletal, visceral, and cortical). When evaluating the total process we should consider the full spectrum of possible information retinoscopy provides. These categories make it possible to view the different aspects of the reflex from three related dimensions. Just as you can describe how physical space can be viewed as consisting of “x,” “y,” “z,” and “time,” it is only when these factors are combined holistically that their relationships can be understood. Likewise, while the retinoscopy observations can be viewed independently, the ability to view the three dimensions as a whole should not be overlooked.

A general overview, using Gesell’s categories, directs the retinoscopist to attend to different features of the reflex. A primary observation related to the skeletal process is to plot optics changes related to the physical distances of multiple observations. This defines individual changes in perceived distances as related to changes in the physical distance from which one observes. The visceral function relates to one’s attention and emotional responses. It helps reveal the rapport the individual has with the task. To determine how the individual is making visceral contact, the retinoscopist should direct their attention to the variation of relative optics from calculated physical optics (This is a measure of the difference between physical distance and projected perceived distance). When the retinoscopy distance is the same as the patient’s perceived distance, optics should be relatively neutral, with a relative equality of the distribution of brightness and color of the reflex. The final area of cortical function is related to thoughts and intellectual interaction with the world. Retinoscopy observations should be on the qualitative aspects of the reflex. They can be described as the subtle changes in the reflex distribution and shifts in central-peripheral equilibration (central brightness spreads when especially insightful to patient). Also, when the patient responds intellectually, there is usually a momentary reduction of peripheral with motion and a rapid change of color and distribution of brightness. These retinoscopic observations will be further elaborated within the paper.

Observing and learning from infants can be attributed to two primary components. First, look at the visual motor development and direct your regimens of care accordingly. Secondly trust and rely on your observations and retinoscopy. Use retinoscopy to observe which lenses and/or small amounts of yoked prisms produce a positive change in the use and ranges of eye-head-body balance and visual motor function. Observe if lenses and yoked prisms provide a stimulus for changing the infant’s eye opening, general motor responses, and changes in awareness. These awareness changes can be dramatic. The child may start to examine the room, be aware of more distances, and change his or her responses to test objects. This can be as simple as the infant beginning to touch the test object. The key is to observe for changes in visual contact distances or in awareness. When an infant sees things more effectively, they invariably will change their own visual behavior.

**History**

The use of retinoscopy for the determination of a refractive condition is credited to a French physician Cuignet in 1873. While static retinoscopy was developed by medicine, dynamic retinoscopy was developed by optometry in the early 20th century. Contributions were made by Bester,\textsuperscript{3} Fry,\textsuperscript{4} Nott,\textsuperscript{5} and Sheard\textsuperscript{6,7} Pascal\textsuperscript{8,9} gives credit to A.J. Cross\textsuperscript{10} who was at Columbia University as the individual responsible for clinical acceptance. The original goal of dynamic retinoscopy was to determine the appropriate lens power for near vision. It later came to be used as a method for evaluating the lag of accommodation. Because dynamic retinoscopy is related to near vision function, it is natural that it should be of primary interest when working with infants. The various techniques developed included Book, Bell, Stress Point, MEM, and Cognitive retinoscopy.
The goal was to make retinoscopic observations of a relaxed, functional and active visual system but with different goals. Book retinoscopy was to evaluate the equality of eye focusing and level of involvement with sequential reading or picture tasks. Bell retinoscopy is a modification of Nott retinoscopy. The goal was to help determine the possible lens prescription for visual near tasks. Stress point retinoscopy was to determine at what distance the individual began to visually avoid. The MEM procedure was designed to more accurately measure the refractive state at near by quickly inserting and removing the measuring lens to eliminate a response to the lens. Cognitive retinoscopy was to determine visual focusing action related to visualized motor tasks or when doing intellectual problem solving.

Skeffington\textsuperscript{11} presented the need for consistent comparisons of retinoscopy findings done at different distances. Streff and Claussen\textsuperscript{12} demonstrated that in a controlled experiment in bell retinoscopy, they arrived at different qualitative measures when using a spot retinoscope versus a streak retinoscope. The experiment later demonstrated that depending upon what aspect of the reflex in spot retinoscopy was observed (central or peripheral), the differences could be replicated. When using a spot scope, the central change and peripheral change were found at different distances. One change matched the results with the streak procedure and the other with the spot procedure. This difference of reflex variables might explain why it is often more successful to make performance based clinical judgments when using a spot retinoscope. When using a streak retinoscope, the observations must be done using a \textit{sequential} processing mode viewing various aspects and meridians selectively. On the other hand, the spot retinoscope allows the retinoscopist the opportunity to \textit{simultaneously} observe all of the facets of the reflex.

\textbf{History of infant retinoscopy}

The qualitative and quantitative aspects of dynamic retinoscopy are related to observed behavior and can be traced to Gesell\textsuperscript{2} and the Yale Clinic of Child Development. Initially the retinoscope was used while an infant was attending to a dangled cat bell. During an examination, Glenna Bullis (a research assistant at the Yale Clinic) asked what would be observed if retinoscopy were done while an infant was looking at a picture book. Vivian Ilg immediately tried the procedure. Her observations led to the development of book retinoscopy. Book retinoscopy was clinically elaborated by Getman,\textsuperscript{13} Apell,\textsuperscript{14} Apell and Lowry,\textsuperscript{15} and Pheiffer.\textsuperscript{16} Bell retinoscopy was developed by Streff and Apell. Kraskin\textsuperscript{17} is credited with stress point retinoscopy while Haynes\textsuperscript{18} and Greenspan developed the monocular estimate method.

The various dynamic techniques often raised more questions than they answered because there were aspects of the observation which seemed to violate optics and thus were not readily understood. The unpublished work conducted during the Renshaw meetings at Ohio State\textsuperscript{19} was responsible for utilizing retinoscopy observations and relating them to human performance. This later was called cognitive retinoscopy. These experiments included retinoscopy while a gymnast visualized trampoline procedures, mentally solving math problems and evaluations conducted at the state prison to determine if retinoscopy reflexes change when an inmate told a lie. The project which caused the most puzzle was the changes in retinoscopy found in a completely non-sighted individual who had healthy eyes. While the subject was engaged in problem solving tasks, there were significant shifts in both the optical quality and quantity (less with-motion). This is confusing and doesn’t seem possible using the model and understanding of what retinoscopy was assumed to be measuring.

Kruger\textsuperscript{20} studied the luminous changes observed in retinoscopy. While he noted a definite relationship between accommodation and brightness, other aspects changed the brightness level as well. From clinical observations, at least some of the brightness changes are likely related to attention and conceptual processing of visual information. As one reviews the history of retinoscopy, it suggests that there is additional information which can be gleaned from this technique. It also presents the question, what are the various factors which make up the reflex? Certainly one of the factors is optics. But even optics raises the question of what we are measuring because the optics can significantly change even when an individual is attending to a constant target and maintaining 20/20 acuity.

Haynes\textsuperscript{21} and Haynes, and White and Held,\textsuperscript{22} while using dynamic retinoscopy found that infants quickly develop an ability to change accommodation. After a careful cross sectional and longitudinal study of changes in infant retinoscopy, they found that the reflex begins to make a shift within the first weeks of life. By the age of 16 weeks, the infants were manifesting an accurate relative change as the scoping distance extended outward to 25 inches. This is often misquoted by stating that infants have accurate accommodation by 16 weeks of age. They do manifest an accurate matching change equivalent to distance change with an optical mismatch (more with motion). The findings demonstrated a learning curve of relative accommodation. This was the measured slope compared to the physical distance. This is no doubt related to the difference in perceived distance.
The changes in relative accommodation are consistent with the development of ambient-focal changes. At birth, the ambient system is highly dominant and is designed to recognize change, but not to stabilize fixation and accommodation. By 16 weeks of age, the macular area is coming into a higher level of development as myelination evolves. The neurological development lends itself as an explanation of why the infant is first aware of change. It also helps explain why as infants are going through neural maturation, they become more accurate in meeting the changes of accommodative demands of the distance. With a developed ability to stabilize fixation and to centrally attend, there is a new potential to detect the differences of crossed and uncrossed peripheral information. The results illustrate the development of a more effective visual skeletal process which then leads to more accurate contact, attention, and increased understanding.

**The skeletal aspects as seen in retinoscopy**

The basic drive of the skeletal system is to reach out and locate objects, lights, and people in space. The related retinoscopy information from different distances is optically locating where an object is in space when done at different distances. The skeletally controlled process is primarily observable motor function (eye control andvergence). The visceral process motor component is mostly involuntary. The cortical is more subtle and apparently has a manifest motor component (note the experiment with the unsighted man and changes when problem solving). Additional qualities of the retinoscopy reflex which are related to visual localization are observable by analyzing the relative accommodation optics and the change in optics (the slope of accommodation to physical distance measurements compared to calculated expected optics). At birth, an infant’s functional infinity (that distance which their visual attention is set) is at the visual contact distance of 6 to 9". This is a critical survival distance because it is the distance of his/her hands (self correction feedback), as well as the distance of their mother’s face when the infant is nursing (social feedback). There are significant measurable changes in retinoscopy reflex and optics response measurements depending upon the infant’s attention. This indicates that: 1) they are either capable of making accurate changes in distance visual contact or 2) they are capable of making relative changes in optics and relative binocular alignment. This occurs when seeing a given distance as if it were nearer or farther. When one accepts Gesell’s research findings that visual contact starts at near and slowly moves farther and farther away, it is logical that a good deal of optical changes we see with a retinoscope are related to the infant’s ability to perceptually manipulate a single distance (this is comparable to an individual doing plus/minus accommodative rock at a single distance; they can see one distance “as if” it had changed) and see it as if it had changed closer or farther (relative accommodation).

An infant’s developmental behavior in exploring an object gives an impression that the infant wants “to take in” or “ingest” that which they are attending to. They want to make physical contact using visceral processes. This may be observed as they reach an object and grasp it (manual manipulation) and immediately move it into their mouth. The mouth serves as the “court of last resorts” to physically and tactually explore as one uses their lips for orientation and tongue for search. Before they can reach an object and move it to their mouth, they rehearse the movement pattern using ocular motor movements. Visual manipulation (as seen when the infant repeatedly looks from their hands to objects in space and then from the objects to their hands) has a similar movement pattern that emulates what the hands will eventually do. It occurs and is practiced earlier through visual motor shifts. This rehearsal of eye movement back and forth from hand to object leads to manual manipulation. This demonstrates that the infants are using their skeletal process to develop a visceral or tangible awareness.

A question immediately arises however. If the infants are spatially pulling in using visual motor processes, why do they manifest an increase in with motion at far as they pull in? To help understand this consider the difference in relative movement and target distance movement. This concept will be further discussed later in detail.

**The visceral aspects of retinoscopy**

When evaluating the skeletal process, we see the need to utilize the reaching and localization function to be able to obtain a position of the object. Accordingly, the relative mismatch of distance and the measured optics serves as an indicator of how the individual is using the visual system to get a closer (or further) feeling of the attention area. It is an indication of how the infant is visually grasping the target or target area. What is the retinoscopy change seen as the infant becomes more visually involved? From retinoscopy observations, there appears to be a high probability that there is an increase in with motion as the infant visually internalizes and a decrease in with as they extend their localization further.
away. This observation is particularly evident when doing retinoscopy as an infant is falling asleep. The motion dulls and goes into considerable with-motion. The dulling of the reflex indicates a loss of cortical contact. (Recall that the dulling observation is a determinant for the measurement in stress-point retinoscopy). It makes sense that the grasping function has become internalized, a retreat into oneself (eye, brain and body). The primary retinoscopy qualities to observe are the amount of optical mismatch and the relative brightness of the reflex. As the infant develops, this process moves from relative accommodation to more accurate physical localization and accommodation.

**Evaluating the cortical processes**

When using a retinoscope the final area to consider is how one can evaluate the cortical action of an infant: the ability to intellectually convert information. There are some historical precedents related to cortical retinoscopy observations. Getman developed a method of analysis for book retinoscopy related to observations of small rapid optical shifts and shifts in brightness. He interpreted his results as different levels of reading ability: 1) learning to read, 2) easy reading and 3) frustration level. Much of the cognitive data appears related to cortical function because the changes were observed and related to changes in thinking, visualization and cortical action.

One of the early cortically related retinoscopy observations occurs when an infant recognizes his/her mother’s face. This can be evident in the first days of life. Early in this paper I stated that to discern cortical action with a retinoscope required the observations of the reflex quality. Changes in brightness and distribution are obvious factors. Other significant variables include: 1) the flexibility of the reflex noting rapid controlled small optics changes (usually less peripheral with motion, possibly only in one meridian), 2) color with emphasis on the distribution of the color, comparing the central and various peripheral changes and 3) changes in the central-peripheral distribution of brightness. During the moment of visualizing or becoming aware of an “ah-ha”, the central peripheral optics change (often the periphery neutralizes or shows slight against-motion). There often is an associated pupil dilation/constriction and a relative binocular alignment shift (a slight flick usually in) at the same time.

A false assumption is often made during retinoscopy. We assume the distance we see between the infant and the target is exactly the same as that which the infant sees. Gesell¹ in his 1949 presentation to the American Academy of Pediatrics, recognized that the hyperopic and myopic measurements often could not be equated to those of an adult. He also noted the danger of assuming the against-motion measure was a direct determinant of myopia as understood in the school age child or the adult. Additionally, he recognized that a “refractive” with-motion measure was not necessarily a determinant of hyperopia. At first these statements may seem to be a contradiction of science. How can with motion not mean behind the target (focusing too far) and against motion mean not in front of the target (focusing too near)?

**Retinoscopy responses when shifting attention while observing a stereoscopic presentation**

One day while in the vision therapy clinic I decided to do retinoscopy while scoping from the target distance (16 inches) as a patient was looking at a three dimensional stereo target. I was sure when the patient manifested against-motion he was observing the nearer target (base-out projection) which I expected to be perceived as closer and smaller. Further when with-motion was observed I assumed that the patient was observing the more distance projection (base-in projection) which I expected to be perceived as farther away and larger.

You can imagine my surprise when I found that I measured relative with-motion when the individual observed the base-out projection (seen as closer). Further, he manifested relative against-motion when perceiving the base-in projection (seen as further away). I had assumed the opposite, that is less plus when viewing the nearer seen target and more plus when viewing the more distant seen target. I first considered that the patient was in a great deal of trouble until I observed more patients and found that this was the expected response. When using a group of optometrists, the same responses were observed.²³

To understand the phenomena, one has to view the demands of the task. The stereogram was placed at a distance of 16 inches. When the patient was projecting the base-out he continued to observe the target presented at 16 inches, but he perceived it to be closer. Likewise, when the patient was projecting the target at 16 inches as if it were farther away (base-in), the shift was into relative against motion. Both of these observations are evidence that a visual and intellectual conversion of the physical presentation has been made. This experiment is consistent and repeatable. It is a dramatic demonstration that when the individual is viewing a given distance as if it had changed, he will project the opposite motion in the retinoscopy reflex than that which he does when shifting to different physical distances. It appears he is focusing at the distance target and converging towards the perceived near target.
This observation which has been overlooked for all these years has tremendous implications. It is logical that during retinoscopy, when one moves beyond an infant’s functional visual contact (the distance in which they have strong motor/sensory agreement) one should observe an increase in with-motion. The with-motion occurs because the infant perceives the target as closer than the target distance. If this is true, then what does the reflex look like when one comes close enough so that the infant can more accurately match perception with action? The with-motion should either disappear or greatly reduce. If the with-motion was a measure of an eye being focused too far out, then one should expect that with-motion would increase as one moves closer to the infant.24

If the above concept is an accurate description of the dynamics of infant’s vision, one should see little or no with motion when scoping inside of the touch distance (the distance of matching skeletal, visceral and cortical processes). I have found that this is invariably the case unless the infant has previously worn a significant amount of plus lenses. Since recognizing this concept I have found that very few infants show even a moderate degree of with motion when they are attending at near (inside of their reach distance).

Clinical implications

Our model sometimes overcomes reality…and we ignore clinical findings that suggest we go outside the model. An obvious factor often overlooked is that our model and thinking greatly influence prescribing visual clinical care. When we accept Gesell’s concepts, namely that accurate vision contact evolves from near to further away it would follow that our primary orientation with infants should be to evaluate visual performance at near. This is contraindicated in the generally accepted optical model, that of neutralizing a stable eye assumed to be paralyzed and the infant being unable to relate to where the accommodation was a measure of an eye being focused too far out, then one should expect that with-motion would increase as one moves closer to the infant. This is usually +1.00 or less and is usually a vast difference from the retinoscopy neutralization at distance. The clinical responses with this approach have been far superior to what I was observing when prescribing lenses to neutralize the distance retinoscopy finding. Since recognizing this concept I have done infant retinoscopy starting at close range and slowly moving away. Most infants show a relatively accurate visual contact (neutral to very low with-motion) when I am presenting the targets within their near functional horizon. As I back away I often observe that they either gradually (the better response) or more dramatically shift into with motion as the distance is increased. This occurs as the retinoscopist moves beyond the infant’s accuracy in localization of the presented physical distance.

This observation indicates that we should reevaluate our model and the implications of what we measure and observe while doing retinoscopy with infants. The traditional model is that one has to do the scoping with the infant’s attention directed at far to relax accommodation. Thus often the evaluation is made outside the distance of physical contact. More recently there has been an increase in the use of cycloplegics with infants. This unfortunately may be done without first evaluating their functional visual world. If so, this occurs at the expense of the visual motor process being paralyzed and the infant being unable to relate to where they make physical contact with their world. In either case, it certainly appears that we need to take an enlightened look at what we are measuring while observing infant retinoscopy. There is a need for a developmental study of infants learning to use relative accommodation along with the cycloplegic results.

In summary, Gesell’s developmentally ordered categories can serve as a useful organization to look at retinoscopy observations, especially with infants. It provides a directional sequence both for guiding observation and as a useful tool to help evaluate an infant’s visual development. When doing retinoscopy it
is apparent that the traditionally held concepts derived for children and adults fail to describe the measurements and observations seen with infants. To provide appropriate evaluation and guidance of infants, we must first measure and observe changes in how they see in their world.

References
19. OEPF. Summer meetings held at Ohio State University, Unpublished Papers, 1959-60.