

Accommodative Amplitude Determination: Pull-away versus Push-up Method

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ABSTRACT

Background: Historically two basic methods have been utilized for measuring accommodative amplitude, the push-up method (originated by Donders) and the minus lens method. The differences between the results are well established and therefore, the two methods have different normative data. In recent years there has been a movement towards a third method, the pull-away method with a certain presumption that it is a more dependable measurement. Previous studies found no significant difference between the results of the two methods, which has lead to the use of the same normative data for both methods. The purpose of this study is to determine whether the assumption that the pull-away method measurements are not statistically different than the push-up method is in fact appropriate.

Methods: Amplitude of accommodation was measured on 79 subjects using both the push-up and the pull-away methods. The age range of the subjects was 7-35 years and they were divided into three separate age groups (7-12, 13-20, 21-35).

Results: A high correlation between the push-up test and the pull-away test was found in all 3 groups (Group 1: $n = 24$; $r = 0.63$; $p < .0005$. Group 2: n

$= 30$; $r = 0.80$; $p < .0005$. Group 3: $n = 25$; $r = 0.91$; $p < .0005$). The t test showed a significant constant difference between both tests in all groups ($p < .0001$).

Conclusion: In this study there was a statistically significant difference between the results of the two methods. While this is not in agreement with a number of previous studies, it is in agreement with known concepts in psychophysical testing. The results would indicate that in order to effectively use the pull-away method, a standardization evaluation is needed which would provide the necessary normative data.

Keywords: accommodation, amplitude, psychophysical testing, push-up, pull-away

Introduction

Optometry has long used psychophysical testing as an essential part of the examination procedure. In psychophysics, experiments seek to determine whether a subject can detect a stimulus, identify it, differentiate between it and another stimulus, and describe the magnitude or nature of this difference.^{1,2} The most common use of psychophysics is in producing scales of human experience of various aspects of physical stimuli. Such is the case when we use subjective refractive examination techniques, heterophoria assessment and accommodative testing. In our accommodative amplitude testing, we essentially use the method of limits psychophysical testing procedure. The subject reports whether he or she detects the stimulus. In the ascending method of limits, some property of the stimulus starts out at a level so low that the stimulus could not be detected and then this level is gradually increased until the participant reports that they are aware of its presence. This is the equivalent of the pull-away method. In the descending method of limits, this is reversed and is the equivalent of the push-up method of assessing

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Koslowe K, Glassman T, Tzanani-Levi C, Shneor E. Accommodative amplitude determination: pull-away versus push-up method. *Optom Vis Dev* 2010;41(1):28-32.

accommodative function. In each case, the threshold is considered to be at the level of the stimulus property at which the stimulus is just detected.² A known disadvantage of both of these methods is that the subject may become accustomed to reporting that they perceive a stimulus and may continue reporting the same way even beyond the threshold (the error of perseveration or habituation).

There are three basic subjective methods of measuring the amplitude of accommodation two of which, the push-up method and the minus lens method, are frequently described in the literature.³⁻⁷

The push-up test requires the patients to accurately report when the target becomes and remains blurred. This point is then referred to the spectacle plane and converted to diopters.

The minus lens technique also relies on the patient's correct identification of the point at which the target becomes blurred. Routinely performed with the target card at 40 centimeters (although some prefer 30 centimeters) minus lenses are added in the spectacle plane in 0.25 diopter steps until the patient reports that the target becomes and remains blurred.

In both of these methods, the end-point that is most frequently cited in the literature is the first sustained blur and not a total blur-out of the target (making it unidentifiable).^{8,9} While one could debate whether a total blur-out point might not be an easier decision for the patient to make this is not within the scope of this paper. Both of the aforementioned methods have inherent difficulties that can affect their clinical usefulness.

The end point of first sustained blur can be a difficult concept for some patients to apply. It is possible for the examiner to "lead" the patient to misinterpret the blur point by encouraging him/her to keep the target clear as long as possible (the concept of sustained blur). This could cause a delay in response that the target is blurred. Other patient related factors that could affect the results include: fear of failing or giving the "wrong" answer, inability to maintain the sustained attention that the task demands, and not asking for clarification if the directions are unclear. Any of these behaviors may lead to inaccurate accommodative test findings when relying on a subjective report of the first sustained blur point both in children as noted by Woerhle⁵ and also in adults.

It is likely that for these and other reasons the search continues for a more reliable method to

perform this test. This third method, newer and therefore less evaluated in the literature is the pull-away test. This requires a target to be pulled away from the patient's spectacle plane until he/she can correctly name the target. Although this method has not been extensively researched, there have been a few studies that have attempted to compare this newer method to previous methods.

Rouse and Ryan³ combined the push-up and the pull-away tests. They proposed first pushing the target until sustained blur, continuing on to the spectacle plane and then pulling it away until identification of the target. This would be somewhat similar to the psychophysical method called the staircase method. In this method, the stimulus starts out at a perceivable level and is lowered after each of the subject's responses, until the subject does not report it. At that point, the stimulus is increased at each step, until the subject reports it, at which point the process is again reversed.² The problem with this method (as performed by Rouse and Ryan) is that the patient was already familiar with the target from the push-up phase and therefore the end-point identification in the pull-away phase may not have been accurate.

Pollock⁴ also compared the push-up and pull-away testing methods. She found no statistical significance in difference between both tests. In her study subjects were not asked to identify the target, but were only required to report clarity or blur. This could affect the accuracy and relevancy of the results, as there was no proof of correct target identification. In addition, the subject population was quite small (n=12).

Woehrle, et al.,⁵ also compared the push-up and the pull-away tests. Their results showed that there was no statistically significant difference between the two tests. This study measured amplitude of accommodation on 25 subjects (age 10-40). However, with the exception of three subjects, all were in the narrow range of 10-14 years of age. So in actuality, there was a very small age range and one could say the study results could only be applied to children in this narrow age range. Although this is not mentioned in the title, the conclusions of the authors and statements throughout the study make it clear that this study was aimed at examining the pull-away method in a pediatric population.

Our current study attempted to compare the two tests on a larger sample (79) with a more representative age range for accommodative testing (ranging from 7-35 in age). In order to further analyze the results,

the groups were divided into three different age sub-groups with a relatively large number of subjects in each group.

Methods

Amplitude of accommodation was measured on 79 subjects. The subjects ranged in age from 7-35 years (average age 22.5, 42 females and 37 males), and were divided into three different age groups 7-12, 13-20 and 21-35. It was felt that this was a natural division into children, teenagers, and adults.

All subjects were given comprehensive vision examinations before performing both tests. Their visual acuity was corrected to 20/20 (6/6) or better in each eye. None of the subjects had any known ocular disease or previously diagnosed accommodation disorder. None of the subjects had a history of taking medication known to affect the accommodative system. All wore their distance manifest refractive correction for the procedures.

The 79 subjects were examined using both the push-up and the pull-away test for determination of amplitude of accommodation. The pull-away test was performed first and the push-up test second. Both methods were completed twice, first by Tanya Glassman (TG) followed immediately by Chana Tzanani-Levi (CTL). Each examiner was unaware of the results obtained by the other examiner for each subject. The examiners used written instructional sets (see Appendix 1) that were read to each subject in order to insure uniformity of the instructional set. All the tests were performed monocularly and only the right eye was tested. The target was shown with normal ambient room illumination as well as direct over-head lamp (100W incandescent bulb). Both methods were performed with the Accommodation Convergence Rule^a (ACR).^{3,10}

The pull-away test was administered by presenting a single unknown 20/20 (6/6) reduced Snellen number (either a 7 or a 4 based on their recognition factor)¹¹ at the spectacle plane. The examiner pulled the target away at a rate of approximately 5 cm/sec. The subject had to call out the number as soon as they could identify it. The distance in centimeters (converted into diopters) between the spectacle plan and the point at which the target was identified was read off the ACR.

Table 1: Summary of results of each age group and entire sample

Age	Pull-away (average)	Push-up (average)
7-12	14.0625 sd=3.163352	16.45833 sd= 2.959571
13-201	10.4 sd=3.041098	13.16 sd=2.688845
21-35	8.94 sd=3.011506	11.1 sd=3.256404
7-35	11.05 sd=3.682595	13.55 sd=3.673881

For the push-up test a single 20/20 (6/6) reduced Snellen number was presented to the subject at 40cm and slowly brought toward the subject at approximately 5 cm/sec. The subject was asked to report first sustained blur. The distance in centimeters (converted into diopters) from the spectacle plane to the target distance was read off the ACR.

The tests were done first by TG using the 7 target for the pull-away method and 4 for the push-up. CTL repeated this procedure using the 4 target for the pull-away and the 7 for the push-up. In total, the procedure was performed on each subject twice. An average value of the two trials for both the pull-away and the push-up method was calculated. Statistical analysis was performed using the correlation test and the *t*-test.

Results

All 79 subjects completed both tests. Graphs 1-3 show the average accommodative amplitude for all subjects using both methods and the difference between the two tests. Table 1 shows a summary of the results of each age group separately and the entire sample as a whole. The correlation test showed a strong correlation between the two accommodative tests in all groups. (Group 1: $n = 24$; $r = 0.63$; $p < .0005$. Group 2: $n = 30$; $r = 0.80$; $p < .0005$. Group 3: $n = 25$; $r = 0.91$; $p < .0005$).

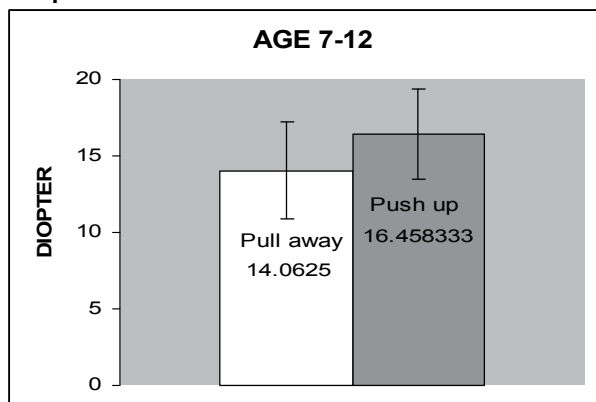
The *t* test was performed on all 3 groups ($p < .0001$) which showed a statistically significant difference between mean values obtained by the push-up test and the pull-away test for all the groups. In the 7-12 age group the difference between the groups was about 2.40 diopters; in the 13-20 age group it was approximately 2.6 diopters and in the 21-35 group it was slightly over 2.00 diopters.

All statistical analyses showed a significant correlation in all age groups. However, with younger subjects, the correlation showed lower results.

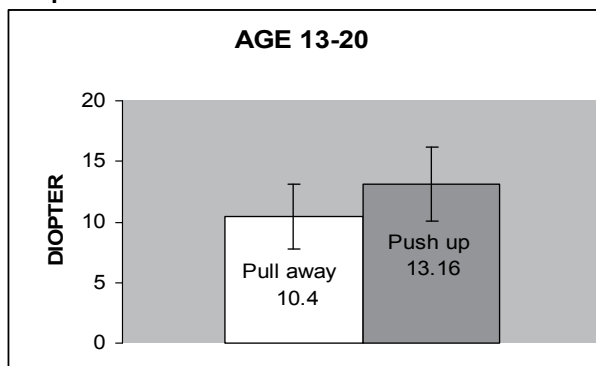
^a Bernell VTP
4016 N Home Street
Mishawaka, IN 46545

Pull-away and Push-up Methods of Accommodative Assessment by Age Group

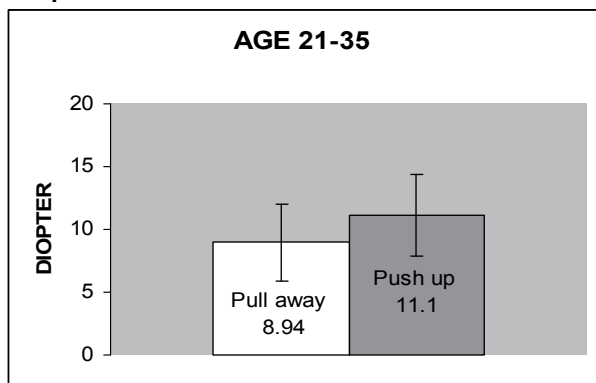
Graph 1



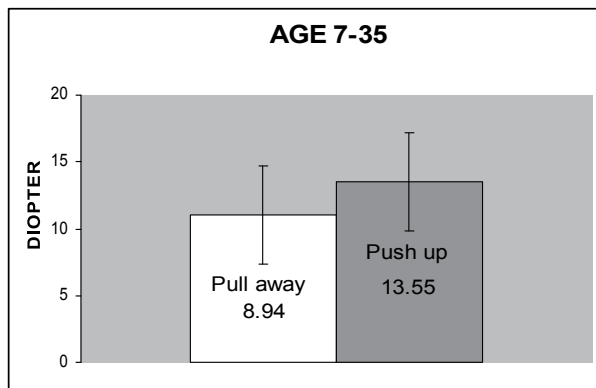
Graph 2



Graph 3



Graph 4



Discussion

Unlike previous researchers, we found a clinically significant difference in the results based on the two tests. The difference in results between our research and previous comparisons could be due to the different methodology. While our methods and instructional set were different from Rouse³ and Pollock,⁴ they were somewhat similar to Woehrle⁵. In the case of the Rouse and Pollock study, the difference in the instructional set can be critical. An example of this is the statement in Borish's Clinical Refraction categorizing the instructional set of a "blur out" criterion as meaningless.⁹ Notwithstanding the similarities, it is equally instructive to point out the differences. The methods used to compare the pull-away and push-up test in the two studies were slightly different. They used random numbers as targets for both tests, which were given in a random order to each subject i.e.: some did the push-up test first and others did the pull-away first, while in the current study this was not done randomly.

Another significant difference is that Woehrle et-al had each test performed three times on a subject (adding up to 6 tests in total: 3-push-up and 3-pull-away). One clinician did the push-up tests and another clinician did the pull-away. In this study however, both tests were done by the one examiner and then repeated by another. In the Woehrle study there was one sample of 25 subjects, random numbers were the targets and each clinician performed one type of test. It is interesting to note that notwithstanding the statistical analysis, 8 of the 25 subjects had differences of 2.00 diopters or more between the two testing methods which compares well with the current study's findings.

In our study, there were 79 subjects, divided into 3 age groups. We only used the numbers 7 and 4 as targets and each of us performed both tests respectively. Our results show the pull-away test consistently giving lower results of total amplitude of accommodation. The significant differences we found between the two tests (the pull-away and push-up tests) can be the result of numerous factors namely:

1. The known psychophysical error of perseveration (habituation) works in opposite directions for the two methods. Therefore, it should exaggerate the amplitude found on the push-up method and minimize the amplitude found on the pull-away method. This is consistent with the direction of difference

that we found. In the push-up method the subject would maintain their last answer (the target is still clear) for a number of responses even if this were no longer true. For the pull-away method the same error would increase the amount of “still blurry” answers. This is based on psychophysical testing methodology and explains why a difference between the two methods is not surprising but actually expected.

2. One could presume that the question (instruction) in the pull-away test is more easily understood; however, this presumption has no particular experimental basis. The entire reason for developing and using this new method is this assumption that it is somehow “better” than the methods it seeks to supplant. This has not yet been shown to be true.
3. It is possible that it is easier to recognize the point where you identify the number (pull-away) than the point of sustained blur (push-up). No research has noted this to be true.
4. The mere fact that the instructional set has been changed may explain the different findings in different test results.

Conclusions

This study has shown a significant difference between the push-up and pull-away methods for testing the amplitude of accommodation over a broad range of age groups. There are apparently many clinicians who use the blur out criterion for their push-up test (notwithstanding the previously mentioned opposition to this criterion). If this criterion were to be used it would guarantee an even greater difference between the two tests as initial sustained blur occurs before the total blur out. This study was not meant to provide new normative criteria for the pull-away method nor does it provide such norms. If the use of the pull-away method is to be continued, it would certainly seem to necessitate a larger study to determine such normative data. Further research would also be necessary to answer the question of which (if any) method is more accurate. Until such further work has been completed, the use of the pull-away method utilizing the normative data taken from the push-up method may be called into question.

Acknowledgments

A much different and shorter version of this study was presented orally with PowerPoint slides to the students and faculty of Haddassah College as completion of a Fourth Year project by two of the authors.

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Appendix 1

Instructional Set for the Accommodative Testing

For the pull-away:

We will be placing a single number before your right eye and slowly pull it away until you are able to recognize the number. As soon as you are able to recognize it please call the number out loud. (This was performed twice on each patient, with different numbers and an average was calculated)

For the push-up:

You can now see a recognizable single number before your right eye (40cm), we will slowly bring it closer towards the eye. You should try and keep seeing the figure clear (with no blur). As soon as you reach a point where the number is blurred and stays blurred (sustained blur), tell us. Please note that this does not necessarily mean that you will not recognize the number. (This was performed twice on each patient, with different numbers. an average was calculated)