Human Heading Perception Based on Form and Motion Combination

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***Abstract*—This paper presents a study on human perception of the heading on the base of motion and form visual cues integration. The authors examine how human age influences this process. Because the visual stimuli are in general uncertain, or in some cases even conflicting, the process of combination is estimated on the base on the well known Normalized Conjunctive Consensus fusion rule, as well as on the base of the more efficient Dezert-Smarandache Theory (DSmT) of plausible and paradoxical reasoning, and more precisely on the probabilistic Proportional Conflict Redistribution rule no.5 defined within it. The main goal is focused on how these fusion rules succeed to model consistent and adequate predictions about both individuals' behavior, and age-contingent groups of individuals [1].**

***Keywords*—Vision; Heading Perception; Form cue; Motion cue; Cues Combination; DSmT; probabilistic Proportional Redistribution rule no.5; Normalized Conjunctive rule.**

I. Introduction

Form and motion information are closely linked and continuously interacting in the human visual system, which takes the advantage to utilize both of these visual characteristics (or so called cues) to make decisions about human heading perception [1] described via the respective rapid eye movement (so called saccades) towards the object of interest position. The cooperation between the form and motion cues becomes very useful and even necessary, when: (i) each cue (motion, form) alone does not supply sufficient information to estimate the proper and accurate heading, or/and, (ii) the uncertainty, associated with the utilized visual cues and the possible conflicts between them influence negatively the process of decision making. The last case relates closely to the effect of the age-related changes throughout the life cycle and to deterioration in the cognitive processes, and consequently in visual information processing due to a variety of factors like cell death, cognitive de-differentiation, increase of internal noise in the visual system. As a result, the contrast sensitivity, self-motion perception, as well as eye movement characteristics are deteriorated in the elderly [2], [3], [4]. To overcome all these difficulties one needs to combine and utilize in an effective way both of cues in order to achieve inferences, more informative and potentially more accurate than if they were obtained by means of a single cue. Integration of information from multiple sources (cues) in a single modality increases the precision of perceptual performance. Such a claim recently has been supported by a list of neurobiological studies, like [5], [6], [7], and also neurophysiological findings exist about neurons responding to both form and motion in some cortical sites (including early visual areas and extrastriate areas) [8], [9].

Inspired and based on these important biological findings of the cue combination effectiveness, the aim of this paper is to investigate how humans integrate motion and form information in the process of decision making about heading direction. The authors will focus on how the human age influences this process, and also whether the human visual system is enable to adapt during the life cycle in order to exploit all available information, providing a sensible and meaningful decision about the problem under concern. In our study we simulate only the directional flow occurring during the forward motion of the observer and not the changes in speed or size of the moving objects that accompanied it. The researcher team will compare human cue combination performance with modelled combination performance, based on particular fusion rules. In the presented study the authors will apply and compare the performances of the following fusion rules: the Normalized Conjunctive Consensus (NCC), and the very recent probabilistic Proportional Conflict Redistribution rule no.5 (pPCR5) defined within DSmT. The novelty of our study consists in applying especially this novel pPCR5 fusion rule to model the human process of form and motion cues integration.

This paper is organized as follows. In section II we briefly present the form and motion combination process, and the principles of the used fusion rules, applied to model the human cue integration. Section III is devoted to the experimental strategy, methods, procedures, stimulus, apparatus, and also subjects participating in the experiments. The results obtained are described and analysed in Section IV. Conclusions are made in Section V.

II. Fusion Rules for Modelling Visual Cue Combination

Various fusion rules exist in the literature to deal with uncertain or even conflicting evidence based on different mathematical models and on different methods for transferring the conflicting mass onto the sensible hypotheses about the problem under consideration. The classical one is Bayesian inference [10], [11] which deals with probabilistic information. The main idea of Bayesian inference is to obtain the most reliable estimate of the state of the world on the base of independent cues combination, i.e. the estimate in which the variance of the resulting combined cue is minimized. But being very sensitive to the sources with the bigger means, it could neglect part of available information, which is not adequate and reliable behavior in cases of conflicting visual cues combination. Bayesian inference has some difficulties to apply, related to the requirements of measurements' statistics and knowledge about the a priori information. Dempster-Shafer Theory (DST) [12], [13] was the first theory for combining uncertain information expressed as basic belief assignments with Dempster's rule. Although appealing in modelling the epistemic uncertainty this theory shows very questionable and controversial results in cases of high (and even low) conflicting sources of evidence [14], [15], [16], [17].

To overcome all these limitations of DST, Dezert-Smarandache Theory of Plausible and Paradoxical Reasoning was developed [18].

DSmT works for any model, which fits adequately with the true nature of the fusion problem under consideration. It is a general mathematical framework for managing and solving problems of uncertain, highly conflicting, imprecise knowledge representation and fusion, and decision making procedures, based on vague, imprecise models for a wide class of static or dynamic fusion problems.

A. Normalized Conjunctive Consensus rule

The Normalized Conjunctive Consensus (NCC) rule is used to combine simultaneously assumed independent visual cues. In the case considered in our paper, the information obtained by the available form and motion cues is characterized by Gaussian likelihood functions with given means $\mu_i, i = 1, 2, ..$ and standard deviations $\sigma_i, i = 1, 2, ..$, defining the uncertainty encountered in data. In case of two independent cues with one-dimensional Gaussian distributions $p_1(x) = \frac{1}{\sigma_1\sqrt{2\pi}} \exp -\frac{1}{2}(\frac{x-\mu_1}{\sigma_1})^2$ and $p_2(x) = \frac{1}{\sigma_2\sqrt{2\pi}} \exp -\frac{1}{2}(\frac{x-\mu_2}{\sigma_2})^2$, the combined distribution based on NCC rule becomes:

$$p_{NCC}(x) = \frac{1}{\sigma_{NCC}\sqrt{2\pi}} \exp -\frac{1}{2}(\frac{x - \mu_{NCC}}{\sigma_{NCC}})^2 \qquad (1)$$

where $\sigma^2_{NCC} = \frac{\sigma_1^2\sigma_2^2}{\sigma_1^2+\sigma_2^2}$ and $\mu_{NCC} = \sigma^2_{NCC}(\frac{\mu_1}{\sigma_1^2} + \frac{\mu_2}{\sigma_2^2})$.

It is characterized with a mean, biased toward the function with the bigger of the two means, similarly to Bayesian estimator. It is optimal, i.e. minimizes the variance of the error estimation, when the original distributions have close mean values. When both cues are in conflict, however, (characterized with distant distributions), NCC rule leads to neglecting part of the available information, because the source with the bigger mean is weighted more heavily. In this case it is reasonable to keep the original distributions in the fused probability density function until it is possible to make reliable decision. This has been done by pPCR5 fusion rule defined in DSmT.

B. Probabilistic Proportional Conflict Redistribution rule no.5

The general principle of all Proportional Conflict Redistribution rules [18], Vol.3 is to: *1*) calculate the conjunctive consensus between sources of evidence (different visual cues) *2*) calculate the total or partial conflicting masses; *3*) redistribute the conflicting mass (total or partial) proportionally on non-empty sets involved in the model according to all integrity constraints. The recently proposed non-Bayesian probabilistic Proportional Conflict Redistribution rule no.5 (pPCR5) [18] is based on the discrete Proportional Conflict Redistribution rule no.5 [18], Vol.3, for combining discrete basic belief assignments. For completeness, we will discuss in brief the main idea behind the discrete PCR5. It comes from the necessity to deal with both uncertain and conflicting information, transferring partial or total conflicting masses proportionally only to non-empty sets involved in the particular conflict and proportionally to their individual masses. Basic belief assignment (bba) represents the knowledge, provided by particular source of information about its belief in the true state of the problem under consideration. Given a frame of hypotheses $\Theta = \{\theta_1, ..., \theta_n\}$, and the so called power set $2^\Theta = \{\emptyset, \theta_1, ..., \theta_n, \theta_1 \cup \theta_2, ..., \theta_1 \cup \theta_2 \cup ... \cup \theta_n\}$, on which the combination is defined, the general basic belief assignment is defined as a mapping $m_s(.) : 2^\Theta \to [0, 1]$, associated with the given source of information s, such that: $m_s(\emptyset) = 0$ and $\sum_{X\in 2^\Theta} m_s(X) = 1$. The quantity $m_s(X)$ represents the mass of belief exactly committed to X. Under Shafer's model assumption of the frame Θ (requiring all the hypotheses to be exclusive and exhaustive), the PCR5 combination rule for only two sources of information is defined as: $m_{PCR5}(\emptyset) = 0$ and $\forall X \in 2^\Theta \setminus \{\emptyset\}$

$$m_{PCR5}(X) = m_{12}(X) + \sum_{\substack{Y\in 2^\Theta\setminus\{X\}\\ X\cap Y=\emptyset}} [\frac{m_1(X)^2 m_2(Y)}{m_1(X) + m_2(Y)} + \frac{m_2(X)^2 m_1(Y)}{m_2(X) + m_1(Y)}] \qquad (2)$$

All sets involved in the formula are in canonical form. The quantity $m_{12}(X)$ corresponds to the conjunctive consensus, i.e: $m_{12}(X) = \sum_{\substack{X_1,X_2\in 2^\Theta \\ X_1\cap X_2=X}} m_1(X_1)m_2(X_2)$. All denominators are different from zero. If a denominator is zero, that fraction is discarded. No matter how big or small the conflicting mass is, PCR5 mathematically does a proper redistribution of the conflicting mass. It is because PCR5 goes backwards on the tracks of the conjunctive rule and redistributes the partial conflicting masses only to the sets involved in the conflict and proportionally to their masses put in the conflict, considering the conjunctive normal form of the partial conflict. PCR5 is quasi-associative and preserves the neutral impact of the vacuous belief assignment. The probabilistic PCR5 (pPCR5) is an extension of discrete PCR5 version to its continuous probabilistic counterpart. Basic belief assignment, involved in discrete PCR5 rule is extended to densities of probabilities of random variables. For two independent sources of information with given Gaussian distributions $p_1(x)$ and $p_2(x)$, the obtained combined result becomes [18]:

$$p_{pPCR5}(x) = p_1(x)\int \frac{p_1(x)p_2(y)}{p_1(x)+p_2(y)}dy + p_2(x)\int \frac{p_2(x)p_1(y)}{p_2(x)+p_1(y)}dy \quad (3)$$

The behavior of pPCR5 fusion rule in comparison to NCC rule (1) could be characterized by two cases below:

Case 1: both densities $p_1(x)$ and $p_2(x)$ are close (Fig.1-case 1). The combined density acts as an amplifier of the information by reducing the variance. Here pPCR5 acts as NCC fusion rule.

Case 2: the densities $p_1(x)$ and $p_2(x)$ are distant (Fig.1-case 2). Then the combined density keeps both original densities (not merging both densities into only one unimodal Gaussian density as NCC rule does), avoiding to neglect a part of the available information.

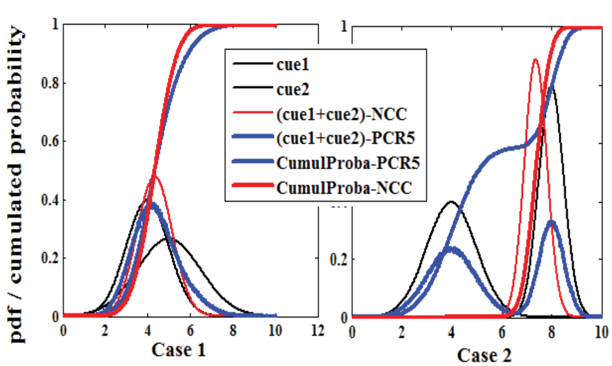

Fig. 1. Performance of pPCR5 fusion rule vs. NCC rule.

This new (from a theoretical point of view) property is very interesting and it presents advantages for practical applications as it will be shown in our particular research. Application of pPCR5 fusion rule assures robustness to the potential errors and allows taking more reliable and adequate decisions in the process of integration of different cues in visual perception.

III. Experiments

A. Stimuli

The stimuli consisted of 50 dots. The dot patterns occupied an area of 15 angular degrees. The stimuli were generated beforehand and contained 100 frames (except the static condition). Each frame lasted 33 msec. The lifetime of the dots was 3 frames, thus on every frame one-third of the dots were randomly re-positioned. For the motion and the combined condition the velocity of the dots was 4 degrees of arc/sec. The stimuli were radial patterns with a focus (center) positioned eccentrically to the middle of the screen. The center of the patterns defined by the orientation of the pairs or the trajectories of the dots could take 7 values to the left or to the right of the midpoint of the screen: 0.67 to 4.67 degrees of arc in steps of 0.67 degrees of arc. Ten different exemplars of patterns for each center and condition were generated. The dots subtended 0.2 degrees of arc.

B. Experimental conditions

Four different experimental conditions were performed:

- **Static (form) condition** The experimental stimuli (Fig.2) consist of dots pairs separated by 2 degrees of arc. The orientation of the virtual lines connecting the dots in 18 pairs intersected in a common point considered the center of the patterns, while the rest 7 pairs had random orientation.
- **Motion condition** In this experiment (Fig.3) 36 points had trajectories that intersected at a common point, while the rest 14 dots had random trajectories.
- **Flicker condition** In this condition (Fig.4) a sequence of random static patterns was presented. As in the static condition the orientation of 18 pairs of dots, separated by 2 degrees of arc pointed to a common center while the rest 7 pairs had different orientation. The sequential presentation of the static patterns created illusory motion, but the trajectories of the apparent motion were random.
- **Combined condition** In this experiment (Fig.5) 18 pairs of dots moved along trajectories towards a common center. The orientation of these pairs was along the motion trajectory. The rest 7 pairs had random trajectories, but again, the orientation defined by the pairs was along the trajectory of motion.

The figures 2-5 correspond to a single frame from the four experimental conditions. The four conditions of the experiment differ by the relative contribution and the order of temporal and spatial integration. In the static conditions the observers needed to find the correspondence of the dots to a pair and to globally integrate this information in order to find the focus of the radial pattern. In the flicker condition on every frame the observers had to integrate the spatial information from the pairs of dots but they could benefit from temporal integration of the sequential patterns that would be equivalent to the presence of a larger number of dot pairs. In the motion conditions the observers had to temporally integrate the displacement of dots in the sequential frames in order to determine their trajectory of motion and to integrate this information in space to determine the focus of the radial pattern. In the combined condition the observers had redundant information as both the trajectory of dot motion and the orientation of the dot pairs provided similar information.

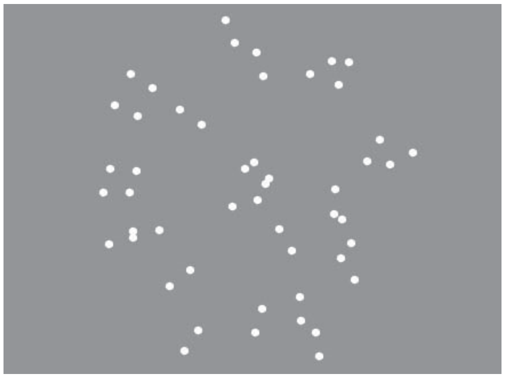

Fig. 2. Static Condition.

Fig. 3. Motion Condition.

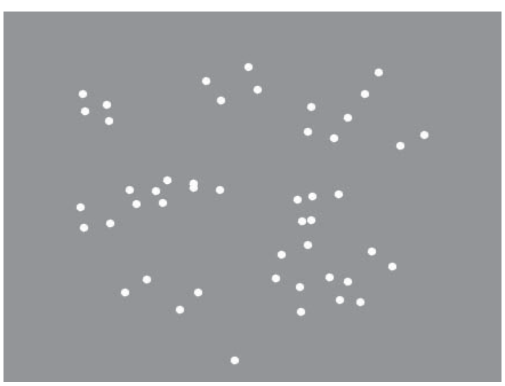

Fig. 4. Flicker Condition.

C. Experimental Procedure

The subject sat at 57 cm from the monitor screen. The stimuli were presented on a gray screen with mean luminance

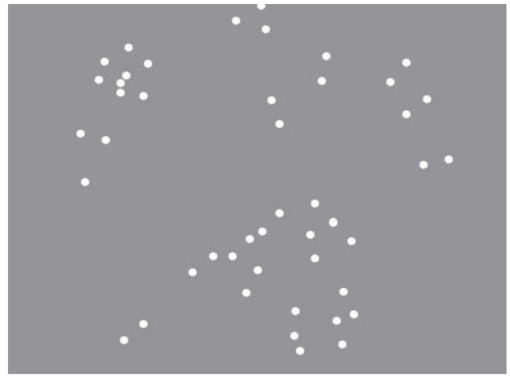

Fig. 5. Combined Condition.

50 cd/m^2. Each stimulus presentation was preceded by a warning signal. A red fixation point with size of 0.8 degrees of arc appeared in the center of the screen for 500 msec. The stimuli were presented simultaneously with the disappearance of the fixation point. The Subjects performed a single-stimulus two-alternative force choice task. They had to continue looking at the position where the fixation point was presented until making a decision where the center of the pattern was (left or right relative to the fixation point). At this moment the subject had to move his/her eyes towards the position of the perceived center and to press the left or the right mouse button depending on whether the perceived center appeared to the left or to the right from the fixation point. If the subject could not make a decision during the 3.3 sec of the stimulus presentation (100 frames), the stimulus disappeared and the screen remained gray until the subject made a response.

D. Method

The method of constant stimuli was used. Each condition was presented in a separate block consisting of 10 presentations for each position of the pattern center (a total of 140 presentations, 7 positions for a center shifted to the left and 7 positions for a center shifted to the right). The order of stimulus presentation was random. Each Subject took part in at least two experiments with 4 blocks for each of the 4 experimental conditions. All conditions were presented in a random order in a single day. The duration of each block depended on the subject performance, but the experiment did not exceed 1 hour. The eye movements of the subjects were registered with Jazz-novo multisensor measurement system (Ober Consulting Sp. z o.o) [20].

E. Apparatus

The stimuli were presented on a 20.1 inch NEC MultiSync LCD monitor with NvidiaQuadro 900XGL graphic board at a refresh rate of 60 Hz and screen resolution 1280/1024 pixels. The experiments were controlled by a custom program developed under Visual C++ and OpenGl.

F. Subjects

The subjects participating in the experiments are divided in three age groups: young (aged from 20 to 34 years), middle (aged 35 to 55 years) and elderly (aged 57 to 84 years). They did not have a whole training session, but they were given examples of stimuli to check whether they understood the task and to get an idea of the stimuli in a given condition.

IV. Performance evaluation of Age-related observers groups

The experimental goal of our study is directed to characterize the human heading perception influenced by: (*i*) form information only (*ii*) motion information only (*iii*) flicker information, i.e temporal integration of form information (*iv*) combined form and motion information. The question is if people rely and base their responses on a single source of information, or on combined one, and also which type of information utilized is more informative in the decision process. The participants belong to three age groups: Young, Middle aged, and Old. Hence, also the influence of human age on the assessment of heading perception will be evaluated. The evaluation is made on the base of experimental psychometric functions, obtained for all different experimental conditions and for each subject in all age-contingent groups. The psychometric function reflects the dependence between a given physical quantity (in this case, the pattern shift from the middle of the screen) and the proportion of subjects responses of a given type, in our case the proportion of responses the pattern center is to the right".

- **Evaluation of heading perception in Young observers group**

  The comparison of the performance in the static, motion and flicker conditions show that in Young group only 2 out of 10 observers have best performance for the static condition, 4 observers effectively utilized the motion information showing best performance in this case, and 4 out of 10 observers show best performance in the flicker condition. For 4 out of 10 observers the null hypothesis of equal psychometric functions for both motion and flicker information could not be rejected, i.e they could be considered as equivalent. These results suggest that the young observers effectively integrate the available information in time. The contribution of the information available in each of these three conditions to the performance of the combined condition differs. Only 1 out of 10 subjects relies mainly on motion, 1 - on the information available in the flicker condition, while 7 out 10 combined effectively the independent sources of information available in the static and motion condition. The performance of averaged (on the base of 10 subjects in the group) young subject is shown on Fig.6.
  For the averaged young subject the psychometric curves associated with static, motion, and flicker information are not distant and the null hypothesis that they do not differ could not be rejected.

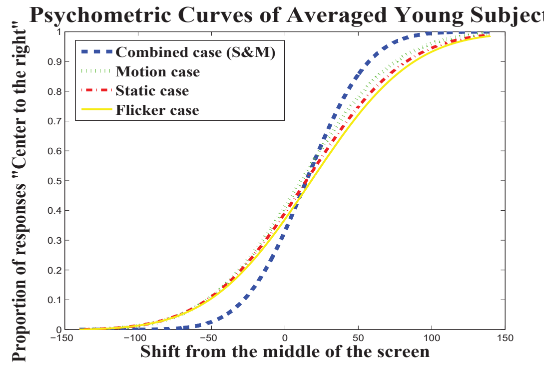

Fig. 6. Psychometric Curves of Averaged Young Subject.

- **Evaluation of heading perception in Middle aged observers group**

  In this age-related group only 1 out of 6 subjects shows better performance in the static condition and 1 out of 6 observers - in the flicker condition. For 1 out of 6 observers the null hypotheses of equal psychometric functions for both motion and static information could not be rejected. For 4 out of 6 observers the null hypothesis for equal psychometric functions for motion and flicker conditions could not be rejected too. As general, the results suggest a small effect of the static information. The results for 4 out of 6 observers show that the results in the combined condition could be successfully predicted based on the performance of the static and motion conditions. The performance of averaged middle aged subject is shown on Fig.7.

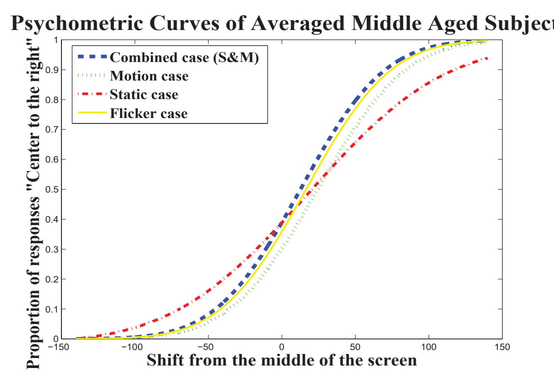

Fig. 7. Psychometric Curves of Averaged Middle aged Subject.

The averaged middle aged observer does not rely mainly on the static information. For him the combined and flicker condition do not differ significantly.

- **Evaluation of heading perception in Old observers group**

The obtained results in Old-age group show that 3 out of 10 observers show best performance in the static, 3 out of 10 - in motion, and 4 out of 10 in the flicker condition. The null hypothesis for equal psychometric functions is valid for: 1 out of 10 for motion and static condition, and for 2 out of 10 - for motion and flicker condition. Six out of 10 subjects utilize combined static and motion information to make their final decision in the combined condition. The performance of averaged old subject is shown on Fig.8. For averaged old subject the null hypotheses that the static and flicker cases do not differ is valid. The averaged old observer relies more on motion information.

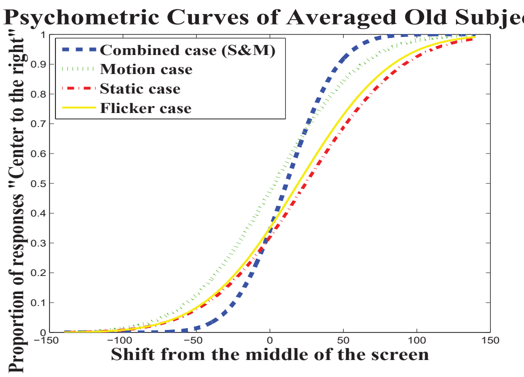

Fig. 8. Psychometric Curves of Averaged Old Subject.

V. pPCR5 and NCC rules performance for predicting human's way of form and motion combination

The main question here is which fusion rule - pPCR5 or NCC used to combine available static and motion information predicts more adequately human cue integration? In order to answer this question we need to make a comparison between experimentally obtained and predicted (via pPCR5 and NCC rules) psychometric functions for combined condition (static and motion), for the three age contingent groups. This comparison is provided on the base of *goodness-of-fit test* [19], one important application of chi-squared criteria: $\chi^2 = \sum_{j=1}^{J} \frac{(O_j - E_j)^2}{E_j}$ where χ^2 is an index of the agreement between an observed(O)/experimental and expected(E)/predicted via particular fusion rule sample values of psychometric function. For our case $J = 14$ represents the number of pattern's shifts from the middle of the screen. The critical value of the test for $\nu = J-1 = 13$ degrees of freedom at assumed $p = 0.1$ is $\chi^2 = 19.81$ [19]. The respective results are given in Table I - for young group, in Table II - for middle aged group, and in Table III - for old persons' group.

In general, the results show that the pPCR5 fusion rule predicts more adequately than NCC rule human performance for the three age groups.

TABLE I
Chi-squared values for young subjects.

Subject	(Form and Motion) pPCR5	(Form and Motion) NCC
1	0.8587	1.8482
2	0.4801	0.8456
3	0.3045	1.2690
4	0.1509	0.9716
5	0.1655	0.1458
6	0.3342	0.7013
7	0.0912	0.1810
8	0.5103	0.8381
9	0.1943	0.2090
10	0.0913	0.1494

TABLE II
Chi-squared values for middle aged subjects.

Subject	(Form and Motion) pPCR5	(Form and Motion) NCC
1	0.3698	0.9854
2	0.1856	0.4934
3	0.4192	0.9341
4	0.9872	1.4716
5	0.2380	1.0143
6	0.2425	0.8456

For young and for middle aged persons (Tables I and II) both fusion rules predict psychometric functions that do not differ significantly from the experimental ones, but the differences in the fits are smaller in case of pPCR5 rule than in case of NCC rule application. The same findings are valid for old people (Table III), but in this group NCC rule show worse performance for subject no.4 (put in bold in Table III) showing the exceeded critical value of $\chi^2 = 19.81$. The reason for this result reflects the situations, when the experimentally obtained psychometric functions, associated with single static and single motion conditions are characterized with distant underlying Gaussian distributions. In this case pPCR5 makes prediction, which models more correctly and adequately human combination behavior. Using NCC rule however, part of available information has been neglected, because the cue with bigger mean was weighted more heavily than the cue with a smaller one (as it was described in Section II).

VI. Common trends of age related observer groups

The goal here is to find the common trend, concerning the performance of the three groups. In order to achieve it, we consider each group as a set of different sources of evidence, associated with each person in the group. That way young group consists of 10 (middle aged of 6, old aged of 10) sources (subjects) of evidence, which should be combined all together via pPCR5 and NCC fusion rules.

The combined individual behaviors in particular group are estimated, reveling its intrinsic behavior as a whole, reducing uncertainties associated with individual performances. All the tested subjects in age groups are considered as independent and equally reliable sources of information, because each subject provides his/her own psychometric function, associated

TABLE III
CHI-SQUARED VALUES FOR OLD SUBJECTS.

Subject	(Form and Motion) pPCR5	(Form and Motion) NCC
1	0.3751	0.7693
2	0.2762	0.5721
3	0.3691	0.4078
4	**2.9287**	**21.0845**
5	0.5418	0.8592
6	0.1652	0.3021
7	0.2013	0.3103
8	0.3984	0.5932
9	0.6712	1.6964
10	0.7152	1.8598

with the static and motion condition and should be taken into account with equal weights to derive these trends.

Our goal is to find out which combinational rule (pPCR5 or NCC) is able to model correctly and adequately such human age-contingent group trends in the process of decision making. The results obtained for experimental and estimated (via the fusion rules) trends, concerning the cues combination groups' performance are presented in Figures 9, 10, and 11.

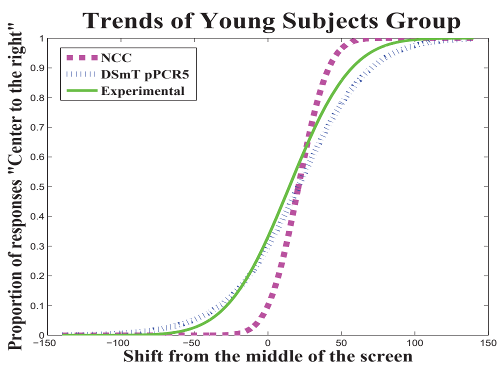

Fig. 9. Trends of Young Subjects Group.

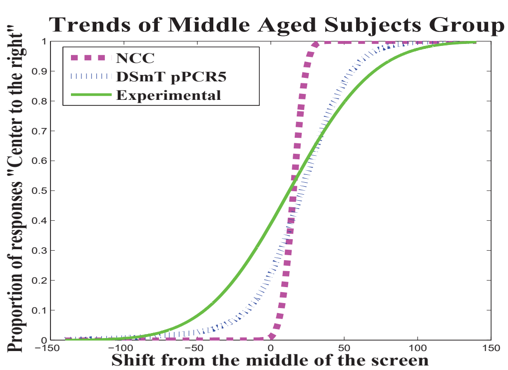

Fig. 10. Trends of Middle aged Subjects Group.

In order to compare the performance of both fusion rules in estimating common trends' prediction the city-block errors between the corresponding triples *young/middle/old* group experimental form and motion combination) - *young/middle/old*

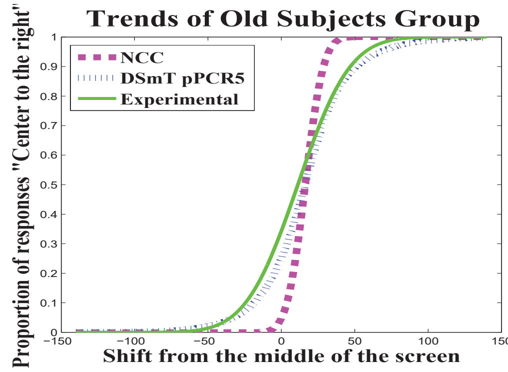

Fig. 11. Trends of Old Subjects Group.

group estimated (via pPCR5 and NCC) form and motion combination are given in Table IV. Results show ultimately that experimentally obtained and those, based on pPCR5 fusion rule are closer and for the three age-contingent groups are more than two times less than those, obtained via NCC fusion rule. pPCR5 fusion rule predicts more correctly the human model of decision making, than NCC rule, utilizing all the available information (**Form** and **Motion**), even in case of conflict. NCC based trends are very sensitive to the sources (different subjects' psychometric functions) with the bigger means, neglecting that way part of the available information and acting as an amplifier of the information by reducing the variances.

TABLE IV
CITY BLOCK ERRORS BETWEEN EXPERIMENTAL AND PREDICTED TRENDS.

	PCR5	NCC
FM Young	0.03	0.10
FM Middle	0.06	0.13
FM Old	0.04	0.12

VII. CONCLUSIONS

This paper presented a study on human heading perception obtained on the base of motion and form visual cues integration. The influence of human age on this process was evaluated. The results obtained show age-related difference in the performance of the subjects in estimating the heading direction based on the combined static (form) and motion information.

Our experimentally obtained data for young observers suggest smaller effect of the static information case and provides indirect evidence that their performance is based more on the temporal integration of information in the motion and flicker conditions. The experimental results for Middle-aged group suggest less effect of the static information and an effect of the order of temporal and spatial integration. The old subjects used to rely more on the motion information. All age-related groups rely on combined (motion and form) information to take their final decisions for heading perception.

A comparison between experimentally obtained and predicted (via pPCR5 and NCC rules) psychometric functions for combined condition (static and motion), for the three age contingent groups was made and estimated on the base of *goodness-of-fit test*, one important application of chi-squared criteria. Results proved that pPCR5 makes prediction, which models more correctly and adequately human combination behavior than NCC, especially in cases of conflicts between the different visual cues.

The combined individual behaviors (the trends) in particular age groups were estimated, reveling its intrinsic behavior as a whole, reducing uncertainties associated with individual observers performance. Results show ultimately that pPCR5 fusion rule, utilizing all the available information - static (form) and motion, even in case of conflict, predicts more correctly the human model of decision making, than NCC rule. That way pPCR5 fusion rule assures preserving the richness of cues data in the process of visual stimuli combination and assures improvement of decision accuracy. pPCR5 describes better the characteristics of the different age groups in decision making based on the motion and form information in heading perception.

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