Investigating Human Visual Behavior by Hidden Markov Models in the Design of Marketing Information

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Abstract. The research demonstrates the use of hidden Markov models (HMMs) in analyzing fixation data recorded by an eye-tracker. The visual activity was registered while performing pairwise comparisons of simple marketing messages. The marketing information was presented in a form of digital leaflets appearing on a computer screen and differed in the components' arrangement and graphical layout. Better variants were selected by clicking on them with a mouse. A simulation experiment was performed to determine best HMMs in terms of information criteria. Seven selected models were presented in detail, four of them graphically illustrated and thoroughly analyzed. The identified hidden states along with predicted transition and emission probabilities allowed for the description of possible subjects' visual behavior. Hypotheses about relations between these strategies and marketing message design factors were also put forward and discussed.

Keywords: Eye tracking · Cognitive modeling · Visual presentation · Digital signage · Advertisement · Human factors · Ergonomics

1 Introduction

Understanding the way people process visual information plays an extremely important role in providing ergonomic recommendations. The effectiveness, efficiency, and satisfaction concerned with graphical messages of various kinds should be taken into account during the design process.

Eye-tracking has recently become a popular technique that facilitate the understanding of human attentional behavior in a variety of contexts. For instance, Grebitus and Roosen [1] examined the influence of the number of attributes and alternatives on the information processing in discrete choice experiments. Muñoz Leiva et al. [2] focused on the roles of engagement and the banner type in advertising effectiveness. Recently, Michalski and Grobelny [3] examined package design graphical factors. Ergonomic analysis of different variants of digital control panels were complemented by an eye-tracking study in [4]. In the work [5], in turn, eye-movement data were used

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for investigating medicine information flyers. More applications can be found, for example, in the literature review presented by Huddleston et al. [6].

The main advantage of applying eye-trackers is the possibility of measuring peoples' visual activities in an objective way. Unfortunately, the registered line of sight provides information only on the so called overt attention [7]. Researchers constantly pursuit methods that would extend the analyses also to covert attention, which cannot be directly observed by eye-tracking. One of the possible approaches involves the use of Markov models. Already in 1986, Ellis and Stark [8] proposed using stochastic first-order Markov process for this purpose. Some further studies also followed this idea, extending it to hidden Markov models (HMMs) where hidden states are interpreted as manifestations of covert attention (e.g., [9–11]). Lately, Chuk et al. [12] used HMM analysis in face recognition tasks. Grobelny and Michalski [13] applied a series of HMMs for visual activity data recorded while performing monitoring tasks on digital control panels. Comparable methodology was involved in the analysis of pairwise comparisons of virtual packages [14].

The present study is a continuation of these studies and employs similar approaches. The general objective is to extend our knowledge about human visual behavior while assessing different versions of advertisement leaflets. HMMs parameters are estimated based on observation fixation sequences derived from the eye tracking data, assumed number of states, and a vocabulary corresponding to the defined areas of interests (AOIs).

2 Overview of the Experiment

The eye-movement activity used in the present research come from the work of Michalski and Ogar [15]. The main goal of that study was to verify the influence of graphic elements of the flyer presenting details about internet packages on preferences of potential customers. Four variants of the leaflet were designed differing in the location of information components and graphical grouping of the leaflet content. The first factor was examined on two levels: package price was situated either directly under the package title in the upper area of the flyer, or at its very bottom. As a consequence of the two possible locations of the price information, the text *Order* changed its place accordingly (compare Fig. 1). The second effect was also specified on two levels. The three types of internet packages were separated either by white, empty spaces or spaces in the color of the flyer background (grey). In the rest of this paper, the former level is called *divided* whereas the second one – *solid*.

Graphical layouts were subjectively assessed by binary pairwise comparisons. Each participant evaluated all possible pairs of investigated stimuli, thus, in one experiment there were six comparisons.

The experiment was conducted in an isolated room equipped with a desk, typical office chair, keyboard, optical computer mouse, and 21" monitor. Subjects' behavior was monitored through a one-way mirror and registered by video cameras. Their visual activity was recorded by a modern SMI RED500 stationary infrared eye-tracker system. The device records eyeball movements at 500 Hz sample rate with 0.4° accuracy.

As a result of a quality analysis of the gathered data, results from 49 out of total 71 experiment participants were explored. There were 16 female and 33 male students from Wrocław University of Science and Technology (Poland). Their age ranged between 19 and 31 with the mean equal 21.9 and standard deviation of 3.0.

Generally, the preferences outcomes revealed higher rates for variants with divided graphical structures and those, with price information placed in the upper part of the leaflet. The visual activity analysis involved heat maps, descriptive statistics of processing and searching measures, along with analyses of variance for fixation durations, number of fixations, and pupil diameters.

3 Modeling Visual Activity by HMMs

Markov models were introduced by a Russian mathematician Markov in 1913 [16]. They deal with states and transitions between them specified by likelihoods of their occurrences. A hidden version of Markov models involves unobserved states that can be identified indirectly. In the present research, a discrete, first-order HMM was employed. It usually consists of a set of hidden states, a group of observations for every state, states' transition probability matrix $\boldsymbol{A}$ with probabilities of switching from one state to another one, emission probabilities matrix $\boldsymbol{B}$, and the starting likelihoods $\boldsymbol{\pi}$. A detailed introduction to HMM is provided by Rabiner [17].

For the experiment briefly described in Sect. 2, a set of AOIs were defined for experimental conditions in a way, graphically demonstrated in Fig. 1. Definitions of all AOIs used in further simulations, their abbreviations, and appearance in comparisons are put together in Table 1. The sequences of fixations registered in those AOIs for all examined subjects were next applied to train HMMs parameters ($\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{\pi}$). The eye tracking data were first elaborated in the SMI BeGaze 3.6 software, next processed in TIBCO Statistica 13.3 package [18]. The HMMs were derived according to the Baum-Welch algorithm [19] taking advantage of procedures and functions developed by Murphy [20]. The maximum number of iterations equaled 1000, and the convergence threshold: 0.0001. HMMs calculations were conducted in Matlab R2018b [21].

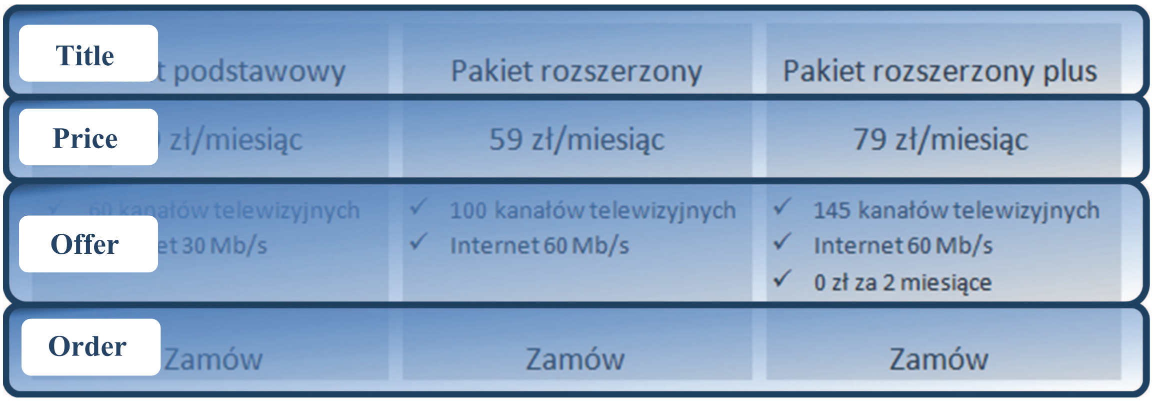

Fig. 1. Defined AOI for a sample stimulus (*divided* and *price up*)

Table 1. Definitions of AOIs, their abbreviations, and appearance in comparisons

	Top leaflet				Bottom leaflet			
	AOI abbreviation	Grouping	Arrangement	AOI type	AOI abbreviation	Grouping	Arrangement	AOI type
Comparison 1	T_S_PU_TI	Solid	Price up	Title	B_D_PU_TI	Divided	Price up	Title
	T_S_PU_PR	Solid	Price up	Price	B_D_PU_PR	Divided	Price up	Price
	T_S_PU_OF	Solid	Price up	Offer	B_D_PU_OF	Divided	Price up	Offer
	T_S_PU_OR	Solid	Price up	Order	B_D_PU_OR	Divided	Price up	Order
Comparison 2	T_S_PD_TI	Solid	Price down	Title	B_D_PD_TI	Divided	Price down	Title
	T_S_PD_OR	Solid	Price down	Order	B_D_PD_OR	Divided	Price down	Order
	T_S_PD_OF	Solid	Price down	Offer	B_D_PD_OF	Divided	Price down	Offer
	T_S_PD_PR	Solid	Price down	Price	B_D_PD_PR	Divided	Price down	Price
Comparison 3	T_S_PU_TI	Solid	Price up	Title	B_S_PD_TI	Solid	Price down	Title
	T_S_PU_PR	Solid	Price up	Price	B_S_PD_OR	Solid	Price down	Order
	T_S_PU_OF	Solid	Price up	Offer	B_S_PD_OF	Solid	Price down	Offer
	T_S_PU_OR	Solid	Price up	Order	B_S_PD_PR	Solid	Price down	Price
Comparison 4	T_D_PU_TI	Divided	Price up	Title	B_D_PD_TI	Divided	Price down	Title
	T_D_PU_PR	Divided	Price up	Price	B_D_PD_OR	Divided	Price down	Order
	T_D_PU_OF	Divided	Price up	Offer	B_D_PD_OF	Divided	Price down	Offer
	T_D_PU_OR	Divided	Price up	Order	B_D_PD_PR	Divided	Price down	Price
Comparison 5	T_S_PU_TI	Solid	Price up	Title	B_D_PD_TI	Divided	Price down	Title
	T_S_PU_PR	Solid	Price up	Price	B_D_PD_OR	Divided	Price down	Order
	T_S_PU_OF	Solid	Price up	Offer	B_D_PD_OF	Divided	Price down	Offer
	T_S_PU_OR	Solid	Price up	Order	B_D_PD_PR	Divided	Price down	Price
Comparison 6	T_D_PU_TI	Divided	Price up	Title	B_S_PD_TI	Solid	Price down	Title
	T_D_PU_PR	Divided	Price up	Price	B_S_PD_OR	Solid	Price down	Order
	T_D_PU_OF	Divided	Price up	Offer	B_S_PD_OF	Solid	Price down	Offer
	T_D_PU_OR	Divided	Price up	Order	B_S_PD_PR	Solid	Price down	Price

3.1 Simulation Experiment

A simulation experiment was designed and conducted to determine the most appropriate number of hidden states, necessary to model the visual behavior registered while performing pairwise comparisons. Overall, 30 conditions were examined. They were differentiated by five possible hidden states (from 2 to 6) and six comparisons (5 states × 6 comparisons).

The HMM estimations depend on starting likelihoods, therefore, 100 single simulations were carried out for each experimental condition with random starting values. All the models were assessed according to Akaike's Information Criterion (AIC) [22], Bayesian Information Criterion (BIC) [23], and log-likelihood values. Obtained minimum values for these criteria suggested the most relevant number of hidden states given the occurrences of fixations in specified areas of interests. The summary of outcomes obtained in these simulations for all 30 conditions are put together in Table 2.

Table 2. The HMM simulation results for all comparisons. Values in brackets denote standard deviations

No	Comparison	No of states	AIC Mean	AIC Min	BIC Mean	BIC Min	Log-likelihood Mean	Log-likelihood Max
1.	**1.**	2	3770 (97)	3737	3878 (97)	3845	-1863 (48)	-1847
2.		**3**	3671 (31)	3648	**3849 (31)**	3825	-1800 (15)	-1788
3.	**S_PU <-> D_PU**	**4**	3605 (44)	3564	**3860 (44)**	**3820**	-1750 (22)	-1730
4.		5	3554 (50)	3497	3899 (50)	3841	-1707 (25)	-1678
5.		6	**3528 (41)**	**3487**	3970 (41)	3930	-1674 (20)	**-1653**
6.	**2.**	2	4485 (106)	4415	4597 (106)	4526	-2221 (53)	-2185
7.		3	4351 (70)	4315	4533 (70)	4498	-2140 (35)	-2122
8.	**S_PD <-> D_PD**	**4**	4262 (64)	4206	**4525 (64)**	**4469**	-2079 (32)	-2051
9.		5	4223 (49)	4172	4577 (49)	4527	-2041 (24)	-2016
10.		6	**4200 (44)**	**4153**	4656 (44)	4609	-2010 (22)	**-1987**
11.	**3.**	2	3892 (79)	3858	4000 (79)	3966	-1924 (39)	-1907
12.		**3**	3727 (45)	3706	**3904 (45)**	**3883**	-1828 (22)	-1817
13.	**S_PU <-> S_PD**	4	3684 (28)	3657	3940 (28)	3913	-1790 (14)	-1777
14.		5	3656 (27)	3628	4001 (27)	3972	-1758 (14)	-1744
15.		6	**3648 (25)**	**3616**	4091 (25)	4058	-1734 (12)	**-1718**
16.	**4.**	2	4294 (105)	4233	4405 (105)	4344	-2125 (53)	-2094
17.		**3**	4150 (57)	4113	**4331 (57)**	**4294**	-2039 (28)	-2020
18.	**D_PU <-> D_PD**	**4**	4070 (39)	4041	**4332 (39)**	4304	-1983 (19)	-1969
19.		5	4028 (36)	3989	4381 (36)	4342	-1944 (18)	-1924
20		6	**4019 (38)**	**3970**	4473 (38)	4423	-1920 (19)	**-1895**
21	**5.**	2	3983 (113)	3888	4092 (113)	3997	-1970 (57)	-1922
22		**3**	3745 (67)	3709	**3924 (67)**	**3887**	-1837 (33)	-1818
23	**S_PU <-> D_PD**	**4**	3671 (65)	3631	3929 (65)	**3889**	-1783 (33)	-1763
24		5	3622 (44)	3574	3970 (44)	3922	-1741 (22)	-1717
25		6	**3607 (37)**	**3563**	4054 (37)	4010	-1714 (18)	**-1691**
26	**6.**	2	3777 (86)	3736	3885 (86)	3844	-1866 (43)	-1846
27		**3**	3654 (61)	3607	**3831 (61)**	**3784**	-1791 (30)	-1767
28	**D_PU <-> S_PD**	4	3583 (29)	3559	3838 (29)	3814	-1739 (15)	-1728
29		5	3548 (41)	3509	3891 (41)	3853	-1704 (21)	-1685
30		6	**3536 (31)**	**3496**	3978 (31)	3938	-1678 (16)	**-1658**

Bearing in mind that smaller values of AIC and BIC indicate more suitable models, the presented results suggest that in comparisons 1 and 2, four-states HMMs are necessary. For all remaining conditions, three-states HMMs are sufficient enough. In the fifth comparison, there is a very small difference in BIC values for 3- and 4-states models. These conclusions are drawn based on the BIC, which is known for recommending more parsimonious solutions with smaller number of states and parameters.

Both AICs and log-likelihood criteria outcomes, suggest 6-states HMMs. The best solutions according to BICs are presented in detail and comprehensively examined in the next section. They are also compared with the preference analysis results.

3.2 Analysis and Discussion of the Best HMMs

In all tables presenting HMM estimated parameters, the second rows include initial states probabilities ($\boldsymbol{\pi}$), next four (or three) rows consist of between-states transition probabilities ($\boldsymbol{A}$), and the remaining rows contain emission probabilities ($\boldsymbol{B}$). The best four- and three-states HMMs proposals for all six comparison types are given in Tables 3, 4, 5, 6, 7, 8 and 9. Overall, we illustrated the models as simplified graphs for three, four-states models that differed considerably in their structure and probability distributions (Fig. 2, 3, 5), and one of the remaining three three-states models, which are very similar to each other.

Table 3. Four states HMM for the first comparison

	S1	S2	S3	S4
$\boldsymbol{\pi}$	**0.86**	0.02	**0.12**	0.00
S1	**0.66**	**0.19**	**0.15**	0.09
S2	**0.12**	**0.65**	0.02	**0.16**
S3	**0.15**	0.00	**0.62**	0.05
S4	0.07	**0.16**	**0.22**	**0.70**
[1]:T_S_PU_TI	0.00	0.00	**0.39**	0.00
[2]:T_S_PU_PR	**0.11**	0.00	**0.55**	0.00
[3]:T_S_PU_OF	**0.52**	0.02	0.03	0.01
[4]:T_S_PU_OR	**0.31**	0.00	0.00	0.02
[5]:B_D_PU_TI	0.06	0.00	0.00	**0.37**
[6]:B_D_PU_PR	0.00	0.06	0.03	**0.56**
[7]:B_D_PU_OF	0.00	**0.73**	0.00	0.02
[8]:B_D_PU_OR	0.00	**0.18**	0.00	0.02

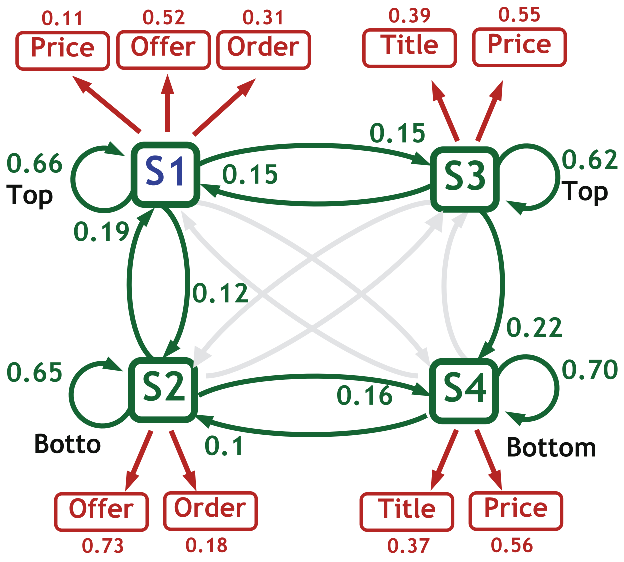

Fig. 2. Four states HMM for the first comparison

The common feature of the all the obtained models is the occurrence of hidden states that can be related to compared leaflets, located either on top or at the bottom of the screen. In four-states models, two hidden states are associated with processing the upper flyer, the two remaining – with the lower leaflet. In the three-states models, two states are related with fixations on the upper variant, whereas one state corresponds to the observation of the lower leaflet.

Analyzing 4-states models for comparisons 1, 2, and 5, it is easy to notice that the states are related to visually examining top and bottom parts of leaflets appearing on top or at the bottom of the screen. One of the three-states models is presented in Fig. 4 and concerns comparison 3. It can be observed that the hidden state associated with the lower flyer is a kind of a juxtaposition of corresponding two states from four-states models. That is, it covers all AOIs from the leaflet located in the lower area of the monitor.

Table 4. Four states HMM for the second comparison

	S1	S2	S3	S4
π	**0.83**	0.00	**0.15**	0.03
S1	**0.59**	**0.19**	**0.12**	**0.15**
S2	**0.21**	**0.67**	**0.11**	0.04
S3	0.03	**0.11**	**0.71**	**0.16**
S4	**0.17**	0.03	0.07	**0.65**
[1]:T_S_PD_TI	0.00	0.00	0.00	**0.33**
[2]:T_S_PD_OR	0.06	0.00	0.00	**0.50**
[3]:T_S_PD_OF	**0.57**	0.00	0.00	**0.17**
[4]:T_S_PD_PR	**0.30**	0.00	0.06	0.00
[5]:B_D_PD_TI	0.08	0.00	**0.58**	0.00
[6]:B_D_PD_OR	0.00	**0.29**	**0.36**	0.00
[7]:B_D_PD_OF	0.00	**0.47**	0.00	0.00
[8]:B_D_PD_PR	0.00	**0.24**	0.00	0.00

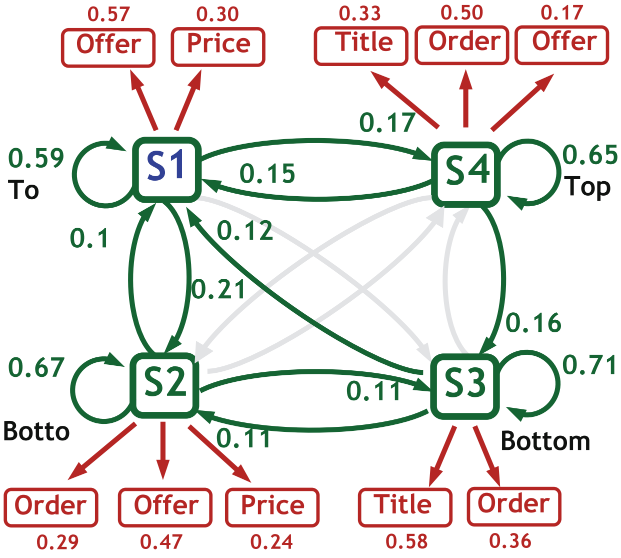

Fig. 3. Four states HMM for the second comparison

The arrays of transition probabilities between hidden states provide some insights on the possible patterns or strategies employed by subjects while performing experimental tasks. For instance, in the model from Fig. 2, taking into account the most probable transitions, one can note that subjects' visual strategy involved the analysis of the key elements of the upper flyer first (S1 → S3), and then move to the lower variant (S3 → S4, and S1 → S2). In the model derived for comparison 2, in turn, participants explored predominantly upper parts for leaflets located both at the top and bottom of the screen (S1 → S2). One should also pay attention to relatively small differences between estimated probabilities that suggest application of various patterns by individual persons or the existence of hybrid visual strategies.

Comparisons 3, 4, and 6 are represented by three-states models. All of them are qualitatively and quantitatively very close to the graphical illustration of the HMM for comparison 3, illustrated in Fig. 4. This model indicate the employment of partial comparison strategy. Offer and Order AOIs in state S1 for the upper leaflet are most often compared with their equivalents situated in the lower area of the screen. In next fixations, subjects examined the remaining, supplementary AOIs. Such a strategy could follow the sequences S1 → (Offer, Order), S1 → S2, S2 → (Order, Offer), S2 → S1, S1 → S3, S3 → (Title, Price), S3 → S2, S2 → (Title, Price).

However, examining Fig. 4, one can come up with a more or less similarly probable strategy of building a full picture of the upper leaflet first, and then move to the lower one: S1 → (Offer, Order), S1 → S3, S3 → (Title, Price), S3 → S2, S2 → (Order, Offer), S2 → (Title, Price).

Table 5. Three states HMM for the third comparison

	S1	**S2**	**S3**
π	**0.89**	0.00	**0.11**
S1	**0.66**	**0.22**	**0.16**
S2	**0.19**	**0.75**	**0.16**
S3	**0.15**	0.03	**0.68**
[1]:T_S_PU_TI	0.00	0.00	**0.41**
[2]:T_S_PU_PR	0.06	0.00	**0.56**
[3]:T_S_PU_OF	**0.51**	0.00	0.02
[4]:T_S_PU_OR	**0.31**	0.00	0.00
[5]:B_S_PD_TI	0.10	**0.15**	0.00
[6]:B_S_PD_OR	0.03	**0.34**	0.01
[7]:B_S_PD_OF	0.00	**0.34**	0.00
[8]:B_S_PD_PR	0.00	**0.17**	0.00

Table 6. Three states HMM for the fourth comparison

	S1	**S2**	**S3**
π	**0.93**	0.00	0.07
S1	**0.57**	**0.18**	**0.19**
S2	**0.20**	**0.75**	**0.14**
S3	**0.24**	0.07	**0.67**
[1]:T_D_PU_TI	0.00	0.00	**0.27**
[2]:T_D_PU_PR	0.01	0.01	**0.62**
[3]:T_D_PU_OF	**0.60**	0.00	0.10
[4]:T_D_PU_OR	**0.32**	0.00	0.00
[5]:B_D_PD_TI	0.06	**0.21**	0.00
[6]:B_D_PD_OR	0.01	**0.33**	0.00
[7]:B_D_PD_OF	0.00	**0.31**	0.00
[8]:B_D_PD_PR	0.00	**0.14**	0.00

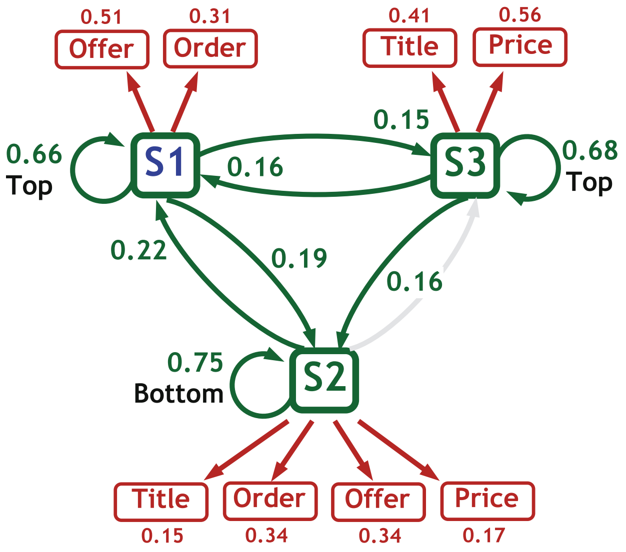

Fig. 4. Three states HMM for the third comparison.

Table 7. Three states HMM for the fifth comparison

	S1	**S2**	**S3**
π	**0.98**	0.00	0.02
S1	**0.65**	**0.15**	**0.14**
S2	**0.18**	**0.81**	**0.13**
S3	**0.16**	0.04	**0.73**
[1]:T_S_PU_TI	0.00	0.00	**0.40**
[2]:T_S_PU_PR	0.06	0.00	**0.55**
[3]:T_S_PU_OF	**0.57**	0.00	0.04
[4]:T_S_PU_OR	**0.30**	0.00	0.00
[5]:B_D_PD_TI	0.07	**0.24**	0.00
[6]:B_D_PD_OR	0.00	**0.36**	0.00
[7]:B_D_PD_OF	0.00	**0.29**	0.00
[8]:B_D_PD_PR	0.01	**0.11**	0.00

Table 8. Three states HMM for the sixth comparison

	S1	**S2**	**S3**
π	**0.90**	0.03	0.07
S1	**0.67**	**0.19**	**0.18**
S2	**0.15**	**0.76**	**0.15**
S3	**0.18**	0.05	**0.67**
[1]:T_D_PU_TI	0.00	0.00	**0.45**
[2]:T_D_PU_PR	0.09	0.00	**0.54**
[3]:T_D_PU_OF	**0.55**	0.00	0.00
[4]:T_D_PU_OR	**0.27**	0.03	0.01
[5]:B_S_PD_TI	0.09	**0.22**	0.00
[6]:B_S_PD_OR	0.00	**0.33**	0.00
[7]:B_S_PD_OF	0.00	**0.31**	0.00
[8]:B_S_PD_PR	0.00	**0.12**	0.00

Table 9. Four states HMM for the fifth comparison

	S1	**S2**	**S3**	**S4**
π	**0.97**	0.03	0.00	0.00
S1	**0.65**	**0.13**	0.04	**0.19**
S2	**0.18**	**0.74**	0.06	0.04
S3	0.04	0.05	**0.72**	0.05
S4	**0.14**	0.08	**0.18**	**0.72**
[1]:T_S_PU_TI	0.00	**0.38**	0.00	0.00
[2]:T_S_PU_PR	0.04	**0.55**	0.00	0.00
[3]:T_S_PU_OF	**0.58**	0.06	0.00	0.00
[4]:T_S_PU_OR	**0.30**	0.00	0.02	0.00
[5]:B_D_PD_TI	0.07	0.00	**0.73**	0.01
[6]:B_D_PD_OR	0.00	0.00	**0.24**	**0.41**
[7]:B_D_PD_OF	0.00	0.00	0.00	**0.42**
[8]:B_D_PD_PR	0.00	0.00	0.00	**0.16**

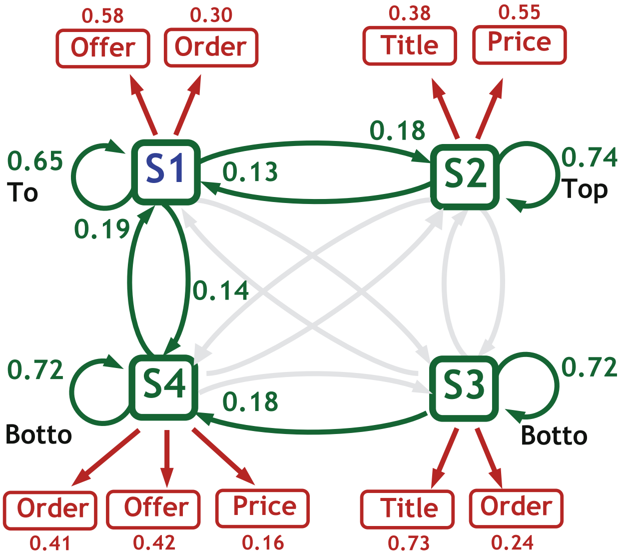

Fig. 5. Four states HMM for the fifth comparison

The detection of two states related with the upper leaflet in every comparison seems to be caused by a general principles of processing visual information by humans [7]. One of the phenomenon observed by researchers is the tendency of starting the analysis from the top part of the visual stimulus [24–26]. Another, theoretical model of attention called zoom-lens [27] may be used here to explain the subjects' visual behavior. First fixations registered in the present experiment correspond to the first step in this model which concerns the general, usually preattentive, processing of the stimulus. In this phase, people probably take advantage of the peripheral vision intensively to organize the whole picture. Such an explanation especially fits to high values of predicted emission probabilities for the Offer AOI in all comparisons. This AOI is located directly at the center of each leaflet. The emission probabilities show that this *general* state may concern either the upper (e.g., in comparison 1) or the lower flyer (in comparisons 2 and 3).

The identification of one or two states for processing the lower leaflet is somewhat surprising. If we assume that bigger number of hidden states is associated with more complex visual tasks [9], the explanation may be twofold.

First, in comparisons 1, 2, and 5, two states were devoted to examining divided leaflets placed at the bottom of the screen. The flyers clear divisions were more expressive in comparison with their solid counterparts. This probably attracted attention in the peripheral vision and required more processing even while focusing on the upper variant.

Secondly, in these three four-states models, the lower versions were considered by subjects as more convincing than the upper ones [19]. In the experiment, participants were to select the more preferred option by mouse clicking on it. Thus, one may presume that one of the states associated with the leaflet at the bottom should represent this acceptance and confirmation stage, since clicking with a mouse requires visual control. It is possible that this task complicates processing of the better leaflet by generating an additional, hidden state.

Irrespective of the presented hypotheses, the obtained and discussed models suggest the existence of a contextual diversification of visual strategies applied during pairwise comparisons of simple stimuli. The differences between HMMs can be coupled with leaflet designs (examined factors), their relative locations (top, bottom), as well as with subjects' preferences expressed towards presented stimuli. The demonstrated results certainly encourage to further explore human visual behavior in various other marketing contexts.

4 Conclusions

The paper shows how modern eye-tracking equipment may be used in examining human visual behavior while processing various aspects of marketing message designs. The collected data can be analyzed in a standard way. However, applying a more sophisticated approach like HMMs, may lead to a discovery of not trivial visual activity patterns. Generally, classic scan path analysis approaches provide information only about overt attention manifestations. HMMs, in turn, allow for making analyses of hidden states that can be linked with covert attention [7]). Therefore, modelling by HMM facilitates deeper and broader search for visual activity patterns concerned with decision and attentional processes.

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