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Entropy Measure to Compare the Internet and Face to Face Surveys

Entropi ölçümü ile İnternet'ten yapılan anketler ve yüz yüze yapılan anketlerin karşılaştırılması

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Technological improvements are utilized in data collection methods as in all areas of life. The expansion of computer and Internet use make it possible to conduct a survey on Internet. Today, many researchers take advantage of this opportunity. This paper seeks to answer whether there is any significant difference between data collection methods as Internet and face to face. To reach this objective response patterns from two data collection methods and from two different scales (Cetscale and Self-Efficacy) are investigated by using an entropy measure. Findings reveal that internet based survey provides less dispersed responses for self-efficacy scale in which social desirability effect is less than Cetscale. Furthermore our results provide evidence that scales have also influences over dispersion of responses.

Keywords: *Entropy, Dispersion, Internet survey, Face-to-face survey*

Jel Codes: *C83, L86, M10, M30.*

Teknolojideki değişim hayatın her alanında olduğu gibi veri toplama yöntemlerinde de kendini göstermektedir. Bilgisayar ve İnternet kullanımının yaygınlaşması araştırmacılara İnternet ortamında da anket yapabilme olanağı sağlamaktadır. Günümüzde de bu olanaktan gittikçe artan bir şekilde faydalanıldığı görülmektedir. Bu çalışmada, Internet ortamında yapılan anketler ile yüz yüze yapılan anketler vasıtasıyla elde edilen veriler arasında farklılık olup olmadığına cevap aranmaktadır. Bu amaçla, iki farklı veri toplama yönteminden ve iki farklı ölçekten (Cetscale ve öz-yeterlik) elde edilen veriler entropi ölçüsü kullanılarak analiz edilmiştir. Bulgular, Internet temelli anketlerin öz-yeterlik ölçeği için daha az dağınık cevaplar sağladığını göstermektedir. Ayrıca sonuçlar, ölçeğin yanıt dağılımı üzerinde de etkisinin olduğuna dair kanıtlar sunmaktadır.

Anahtar Kelimeler: *Entropi, Yayılım, İnternet anketi, Yüz yüze anket*

Jel Kodları: *C83, L86, M10, M30.*

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1. INTRODUCTION

Advances in computer and information technology have led computer based surveys becoming an important medium for gathering data for social sciences (Wang et al., 2013) and online survey methodology has proliferated in line with the rapid diffusion of the Internet. Thus scientific articles which constituted Internet based data collection methods have been widely published for the last two decades. Nevertheless though one of the most prevalent question have been comparability of Internet based (IB) and Face To Face (F2F) surveys in psychology and social research literature, researchers especially freshmen have adopted Internet as the primary data collection medium without questioning the issue.

IB surveys provide numerous advantages to motivate the researchers and the one of most important advantages is that its low cost vis-a-vis traditional methods (Couper et al., 2007). Marginal cost of each new respondent is almost free (van Gelder et al., 2010; Braunsberger et al., 2007). IB surveys also allow for greater flexibility in design (Beuckelaer, & Lievens, 2009) and whenever needed text, audio and/or video can separately or collectively be used, which is almost impossible with conventional methods (Chang, & Krosnick, 2009; Witte 2009 p. 287). IB surveys offers a borderless geographical reach (Wang et al., 2013; Lefever et al., 2007; Beuckelaer, & Lievens, 2009). Thus huge budgets are no longer needed to conduct serious and worldwide surveys (e.g., Couper, & Miller, 2008). Furthermore, virtual snowball sampling facilitates to get access into "hard to involve" population, while expanding sample size and the scope of the study (Gregori, & Baltar, 2013). Obviously ease of implementation, low cost and borderless features of IB surveys leads democratization of research (Kaplowitz et al., 2004; Frippiat, & Marquis, 2010). Electronic forms of surveys do not suffer from human made coding errors (Beuckelaer, & Lievens, 2009) and when sensitive topics are being surveyed IB surveys frequently yielded less socially desirable results (Mohorko, Leeuw, & Hox, 2011).

However, mainly based on the differences of demographic profiles of Internet users, IB survey respondents and F2F survey respondents may not be homogeneous, leading research expectations about existence of inevitable differences in responses due to methods of survey administrations (McDonald, & Adam, 2003). Though limitations of IB surveys cannot be denied, this by no means IB surveys should not be considered as acceptable as other survey methods (Harrison, & Christie, 2004). Comparison of IB surveys with F2F surveys from different perspectives, would expand horizons of researchers whilst drawing their conclusions. From this point of view; the current study aims to compare the IB and F2F surveys results using entropy measure.

2. IB VS F2F SURVEYS in the LITERATURE

Since IB surveys offer numerous advantages, they have been used as the primary data collection medium in social sciences for almost twenty years (Frippiat, & Marquis, 2010). However, findings of IB surveys are consistent with those from F2F surveys remains in question (Wang et al., 2013), some research has been focused on determining the comparability of F2F with IB data collection methods (Weigold et al., 2013; Weigold et al., 2016). Comparisons of IB surveys and F2F surveys are frequently used the same measure with differing in method of administration to test whether the same results to be yielded

(Homola, Jackson, & Gill, 2016). However, even though limited some researches to focus on comparing variations among findings makes the topic more interesting for further studies.

Researchers are almost in consensus that there are heterogeneities among Internet users and non-users at least some demographic profiles, on their ages for instance. Internet is popular amongst youngsters but it is relatively unpopular for older ages. Naturally, the way of thinking and interpreting the cases would not be similar and differ significantly between the Internet user and non-user (Bech, & Kristensen, 2009; Ilieva et al., 2002; Erens, et al., 2014).

Earlier Stanton (1998) surveyed 231 professional employees by using IB and F2F as survey administration methods. Findings discovered that IB data are comparable to the F2F data in terms of item variability. Factor structure of items forming a scale would not differ across data collection formats. Correlations between scales were also same regardless of data collection medium.

Van de Looij-Jansen, & de Wilde (2008) conducted a research as part of Youth Health Monitor of Rotterdam project. Secondary schools' (agreed to take part of the research) all third grade classes' pupils were randomly assigned either IB or F2F condition. Findings did not revealed significant differences between IB and F2F based studies.

Lewis, Watson, & White (2009) examined IB vs F2F survey effect from the perspectives of Australian drivers' or cyclists' license holders. 46.8% participants were completed the IB version while the rest 53.2% of the participants completed the F2F version of the same measure. Researchers concluded that the majority of mean comparisons between the two conditions were equivalent.

Beuckelaer, & Lievens, (2009) extended the scope of their survey by collecting data from 52461 respondents in 16 countries. This was the first ever study conducted in a large number of countries of this question. Results of SEM analysis indicated evidences for scalar equivalence of the multi-item survey instrument across IB and F2F surveys almost all surveyed countries Beuckelaer, & Lievens, (2009) provides an empirical justification for using, combining, and comparing data from mixed-mode surveys in various countries.

Bennink et al. (2013) compared the F2F Dutch European Values Study of 2008 with time-parallel Dutch Longitudinal Internet Studies for the Social Sciences panel. Samples were containing 1154 and 3339 respondents respectively. Findings have demonstrated that F2F and internet modes of research do not produce identical results.

Wang et al's., (2013) study conducted with 401 undergraduate students in Taiwan, and findings revealed significant differences between the two administration methods. This research also signals that IB format might be less reliable than F2F format surveys.

With the growth of IB surveys, self-selected respondents have feared researchers due to professional respondents. The main concern about professional respondents is that they participate a survey simply for the incentives and thus may provide lower quality data. However Leeuw, & Mathijsse's (2016) findings nullified such concerns, providing empirical evidences which do not support to the premise as such professional respondents poses a serious threat to data quality.

Homola, Jackson, & Gill (2016) develop entropy measure of variability which is commonly used measure in physics and communication studies to convey levels of information in a given system or message. Entropy measure is appropriate for describing measurement variability in categorical data where measures of variance that assume continuous data, such as the standard deviation, are not appropriate. Therefore entropy measure could be useful for finding differences in how respondents react to the exact same question in surveys conducted using two different data collection methods, IB and F2F. Homola, et al.,'s (2016) study revealed that entropy of internet survey's responses are less than entropy of face to face survey's responses for 4 to 11 point items. This implies that respondents in internet sample feel more comfortable to answer the questions with more confidence.

3. ENTROPY MEASURE: DEFINITION AND FEATURES

Since comparison between IB and F2Fsurveys is needed, the concept of equality has emerged in the relevant literature and two one sided test approach as generally been adopted. Homola, Jakcson, & Gill (2016) introduced a measure into social sciences known as entropy measure. Their departure point is that the variance measure $Var(X) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$ is not appropriate for discrete data and variance assumes equally spaced interval data. Likert scaled surveys on the other hand may violate the assumptions about the distributions of normality and relying the central limit theorem for approximation to continuous data if the sample size is not enough large. But entropy measure makes absolutely no assumptions about the distribution of variability of uncertainty (Shannon 1948 from Homola, Jakcson, & Gill 2016).

As a basic concept in thermodynamic, statistics and information theory; *Entropy* can be defined as a measure or mathematical definition of disruption amount in a layout, darkness and uncertainty in a system or message (Shannon 1948).

Let $\mathbf{a_1}$, $\mathbf{a_2}$,…, $\mathbf{a_n}$ be the results and $\mathbf{p_1}$, $\mathbf{p_2}$,…, $\mathbf{p_n}$ be the probability of the results in a system or message symbolized by A. These probabilities have the following properties;

$\mathbf{p_i} \geq 0$ for $\forall \mathbf{i} = 1,2,\ldots,\mathbf{n}$ and

$\sum_{\mathbf{i}=1}^{\mathbf{n}} \mathbf{p_i} = 1$.

Hence, the system or experiment of A can be described as follows:

$$\mathbf{A} = \begin{pmatrix} \mathbf{a_1} & \mathbf{a_2} & \cdots & \mathbf{a_n} \\ \mathbf{p_1} & \mathbf{p_2} & \cdots & \mathbf{p_n} \end{pmatrix} \quad (1)$$

The uncertainty of the probability space related to the intensity of the probabilities in (1) is inversely proportional. If the probability is concentrated in i[th] result, $\mathbf{p_j} = 0$ (for all $\mathbf{i} \neq \mathbf{j}$). In this case, the result of the experiment is certain, since there is no uncertainty and density would be the greatest. Otherwise, if all results in the experiment are equally probable $(\mathbf{p_i} = \frac{1}{\mathbf{n}}, \quad \mathbf{i} = 1,2,\ldots,\mathbf{n})$ the density is the smallest and the uncertainty of the results would be the greatest.

As a measure of the uncertainty of the probability space, Shannon (1948) proposed entropy, which is the average amount of information contained in the experimental results. Experiment A of (1) produce the $a_1, a_2, \ldots, a_n$ messages with the $p_1, p_2, \ldots, p_n$ probabilities. The amount of information contained in each of the messages of an experiment is defined by Shannon (1948) as follows:

$$I(a_i) = \log \frac{1}{p_i} = -\log p_i \quad i = 1,2,\ldots,n \tag{2}$$

The expression in (2) is called the amount of information of a message (result or event). The entropy or average amount of information of sample space or information source is defined as expectation value of the amount of information by Shannon (1948) as follows:

$$H(p_1, p_2, \ldots, p_n) = E\left[I(a_i)\right] = -\sum_{i=1}^{n} p_i \log p_i \tag{3}$$

Shannon has associated the amount of information within a message, with the uncertainty of the message. Hence, the entropy function given in (3) is interpreted both as a measure of uncertainty and as a measure of the amount of information. The properties of the entropy function are numerous and can be found in Reza (1961), Aczel, & Daroczy (1975), Mathai, & Rathie (1975) and others. Here some important features of Shannon's entropy function are summarized as follows:

1. $H(p_1, p_2, \ldots, p_n)$ is continues for each p_i in $[0,1]$.
2. $H(p_1, p_2, \ldots, p_n) \geq 0$.
3. If for any i, $p_i = 1$ then $p_j = 0$ $(i \neq j)$ and $H(p_1, p_2, \ldots, p_n) = 0$. The entropy of exact event is zero.
4. For each $(p_1, p_2, \ldots, p_n)$ and each permutation on $\{1,2,\ldots,n\}$,
   $H(p_k, 1-p_k) = H(1-p_k, p_k) \quad ; k = 1,2,\ldots,n$
5. $H(\frac{1}{2}, \frac{1}{2}) = 1$.
6. $H(p_1, p_2, \ldots, p_n, 0) = H(p_1, p_2, \ldots, p_n)$
7. For all $(p_1, p_2, \ldots, p_n)$ and $(q_1, q_2, \ldots, q_m)$ probability sets and $p_n = \sum_{j=1}^{m} q_j$
   $$H(p_1, p_2, \ldots, p_n, q_1, q_2, \ldots, q_m) = H(p_1, p_2, \ldots, p_n) + p_n H\left(\frac{q_1}{p_n}, \frac{q_2}{p_n}, \ldots, \frac{q_m}{p_n}\right)$$
8. If $p_1 = p_2 = \ldots = p_n$ then $H(p_1, p_2, \ldots, p_n)$ has the largest value.
   $$H(p_1, p_2, \ldots, p_n, 0) \leq H\left(\frac{1}{n}, \frac{1}{n}, \ldots, \frac{1}{n}\right) = \log n$$

Lower and upper bound of entropy function can be written from above properties as:

$$0 \leq H(p_1, p_2, \ldots, p_n) \leq \log n \tag{4}$$

After Shannon's study of basic theory of knowledge, a new scientific discipline has emerged in accordance with the advances in technology and communication theory, then studies both discovering the concept of entropy and utilizing entropy concept had accelerated. Furthermore Entropy measure has adopted in many research fields such as applied statistics,

computer science, psychology, economics, hydrology, geology and geophysics, etc. Sonuga (1972) applied the maximization entropy principle of frequency analyzes of hydrology and obtained the probability function of hydrological data with the help of the mean and standard deviation, without any prior knowledge. The employment in hydrology-based and non-hydrology-based industries in the Tennessee Valley region of the United States was compared by Garrison, & Paulson (1973) by using entropy as a measure.

Kullback, & Leibler (1951) examined the concept of information theory, with help of entropy, and have proposed a theoretical predictive method of information by interpreting entropy as a discriminant function. Kullback used results obtained in multivariate analysis and published the book titled Knowledge Theory and Statistics in 1959. Jaynes (1957) studied the entropy maximizing probability functions under certain constraints, starting from the concept of entropy. Theil (1967) applied the concept of knowledge theory to economics and implemented the concepts of probability, which is the basis of knowledge theory of the economics.

4. RESEARCH DESIGN AND METHODOLOGY

Two different scales are utilized for the sake of current study. The first scale is 17-item CETSCALE of Shimp, & Sharma (1987), the second scale is the self-efficacy scale of Sherer et al. (1982). To balance the number of questions in each scales, 17 questions of self-efficacy scale was deliberately chosen. Both scales are widely used in many researches, thus both measures are assumed to be well structured. Turkish translations of CETSCALE and self-efficacy scale was copied from Eroğlu, & Sarı (2011) and Gözüm, & Aksayan (1999) respectively.

The effect of three factors over the responses is the main concern of our study. The effect of the data collection method, the measure itself and the respondents' educational background as a reflection of their way of thinking as qualitative and quantitative proclivity.

Active students of Faculty of Economics and Administrative Sciences, and Faculty of Engineering during 2015-2016 of Pamukkale University, who attend lectures were selected as the sample of the study[6]. Sampling plan is presented in Table 1.

Table 1. Number of students in samples

Stratas	**Strata Size**	**Sample Size**
Respondents of faculty of economics and administrative sciences (FEAS)	8396	163
Respondents of faculty of engineering (FE)	5639	110
Total	14045	273

The planned and performed sample sizes according to the scale type, data collection method and background type are presented in Table 2.

[6] Turkish university placement exam places students based on their orientation towards qualitative and quantitative thinking ability. Faculty of Economics and Administrative Sciences' students are assumed to be qualitative thinking proclivity and Faculty of Engineering students are assumed to be quantitative thinking proclivity. Therefore faculty based distinction enables us to examine whether there is any difference due to the way of their thinking.

Table 2. Sampling: planned and performed

Data Collection Method	Scale	Faculty	Sizes	
			Planned	Performed
Face To Face	Cetscale	FEAS	30	35
Face To Face	Cetscale	FE	30	81
Face To Face	Self-efficacy	FEAS	30	43
Face To Face	Self-efficacy	FE	30	81
Internet	Cetscale	FEAS	30	47
Internet	Cetscale	FE	30	37
Internet	Self-efficacy	FEAS	30	38
Internet	Self-efficacy	FE	30	31
		Total	240	396

5. FINDINGS

In order to get further insight about how entropy can be utilized as a measure of uncertainty between categorical answers, let's consider the first statement of Cetscale: "*Turkish people should prefer Turkish products instead of foreign products*". As with other items in the scales, the respondents were asked to respond using a 5-point Likert scale. Response distributions are given in Table 3.

Table 3. Response distributions

Mode	completely disagree (1)	Disagree (2)	neither agree nor disagree (3)	Agree (4)	completely agree (5)	n
F2F	9.2%	19.2%	9.2%	%34.2	27.6%	76
IB	9.5%	14.3%	16.7%	%27.4	32.1%	84

Shannon's entropy measure in (3) is calculated for each question. These calculations were made separately for each method, (IB and F2F), orientation (qualitative vs quantitative) and measure (Cetscale vs self-efficacy) and, descriptive statistics and t statistics for independent binary comparisons were obtained as summarized in Table 4.

Entropy measure for this distribution should be calculated with (3) as follows:

$$\mathbf{H}_{\mathbf{F2F-CS}}(\mathbf{p}_1,\mathbf{p}_2,\mathbf{p}_3,\mathbf{p}_4,\mathbf{p}_5) = -\sum_{i=1}^{5}\mathbf{p}_i \ln \mathbf{p}_i$$

$$= -\left[0.092\ln(0.092) + 0.192\ln(0.192) + 0.092\ln(0.092) + 0.342\ln(0.342) + 0.276\ln(0.276)\right]$$

$$= 1.4781$$

$$\mathbf{H}_{\mathbf{Internet-CS}}(\mathbf{p}_1,\mathbf{p}_2,\mathbf{p}_3,\mathbf{p}_4,\mathbf{p}_5) = -\sum_{i=1}^{5}\mathbf{p}_i \ln \mathbf{p}_i$$

$$= -\left[0.095\ln(0.095) + 0.143\ln(0.143) + 0.167\ln(0.167) + 0.274\ln(0.274) + 0.321\ln(0.321)\right]$$

$$= 1.5201$$

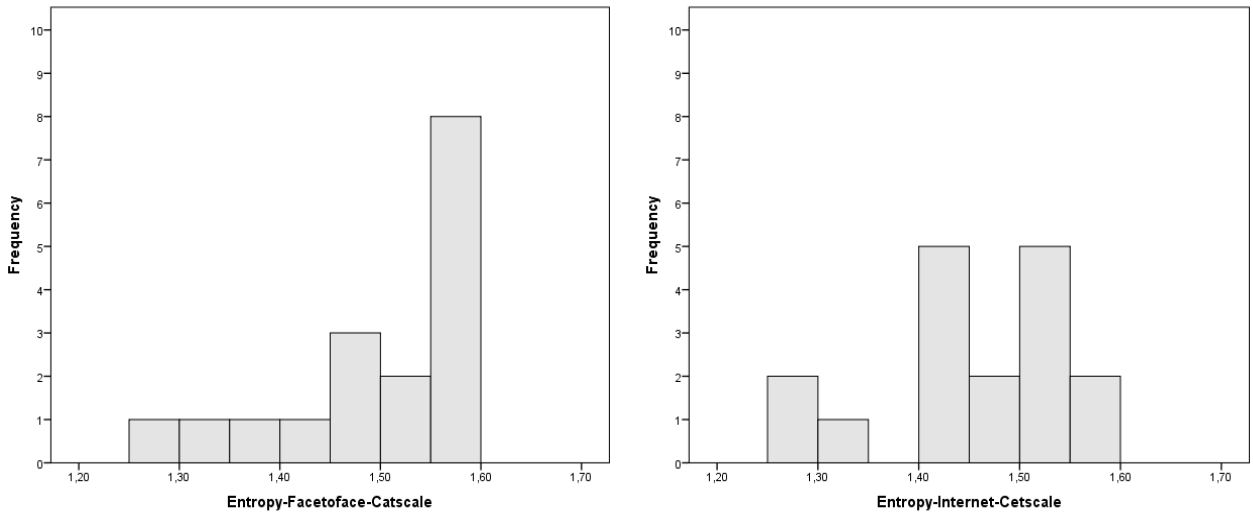
Since $H_{Internet\text{-}CS}$ is greater than $H_{F2F\text{-}CS}$,the IB survey produces more variability and greater uncertainty than F2F survey. It can be said that the amount of information obtained from IB surveys is much more than the amount of information from F2F for this specific question of interest above.

Table 4. Descriptive Statistics and t-tests

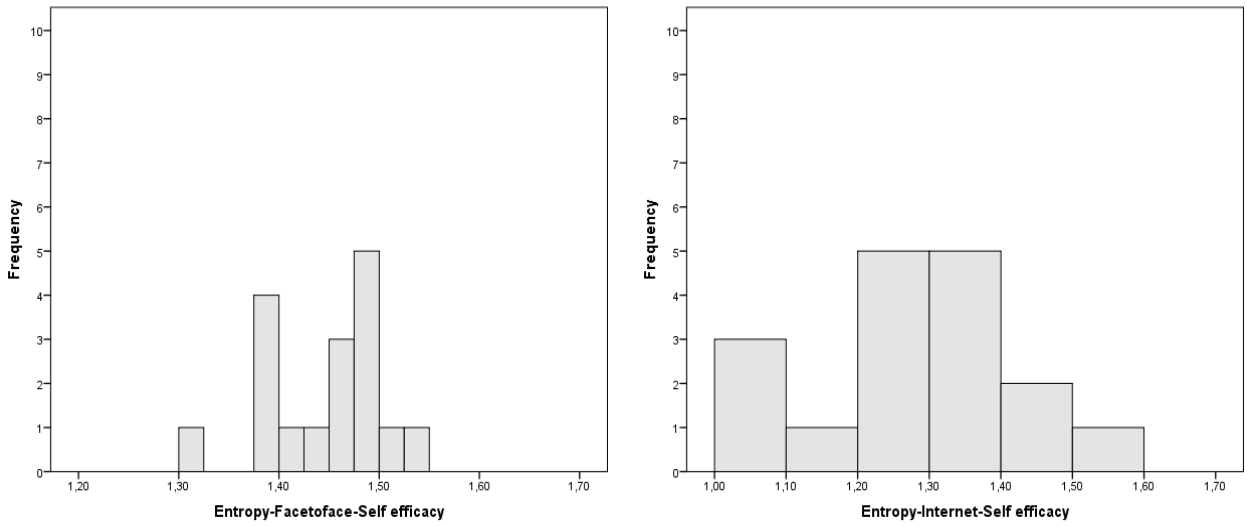
Scale	Orientation	Mode	Mean	Variance	Minumum	Maximum	t-values	p-values
Cetscale	Overall	Face To Face	1.4963	0.0101	1.2659	1.5979	1.2554	0.2184
		Internet	1.4548	0.0084	1.2750	1.5782		
Self-efficacy	Overall	Face To Face	1.4439	0.0031	1.3186	1.5291	4.5042	0.0002*
		Internet	1.2707	0.0220	1.0101	1.5724		
Cetscale	Qualitative	Face To Face	1.4122	0.0172	1.1681	1.5919	-1.2629	0.2160
		Internet	1.4640	0.0114	1.2720	1.6029		
	Quantitative	Face To Face	1.4886	0.0095	1.2783	1.5973	3.1766	0.0033*
		Internet	1.3793	0.0107	1.1327	1.5223		
Self-efficacy	Qualitative	Face To Face	1.3537	0.0081	1.1904	1.4776	2.4919	0.0191*
		Internet	1.2504	0.0211	1.0232	1.4984		
	Quantitative	Face To Face	1.4720	0.0018	1.3842	1.5438	5.7976	0.0000*
		Internet	1.2286	0.0281	0.9351	1.5800		

Based on the Cetscale the mean entropy measure is 1.4963 for F2F and 1.4548 for the. According to t test performed, these two means are not statistically different. In other words one can say that uncertainty of the responses of the Cetscale scale does not significantly different in terms of data collection method. Figure 1 (a) shows that the shapes of the distributions of entropies for two data collection methods based on Cetscale are almost the same.

In the case of self-efficacy scale however, F2F mode yielded 1.4439 as the mean entropy while IB mode yielding 1.277 mean entropy. Findings reveal that there is statistically significant difference between means of F2F and IB modes for self-efficacy scale. The mean entropy value or uncertainty in responses of IB survey is less than that of F2F survey. In Figure 1 (b) it can be said that shape of histogram for IB survey is different from shape of histogram for F2F survey in self-efficacy scale.



(a)



(b)

Figure 1. The histograms of the entropies for the scales and the data collection methods

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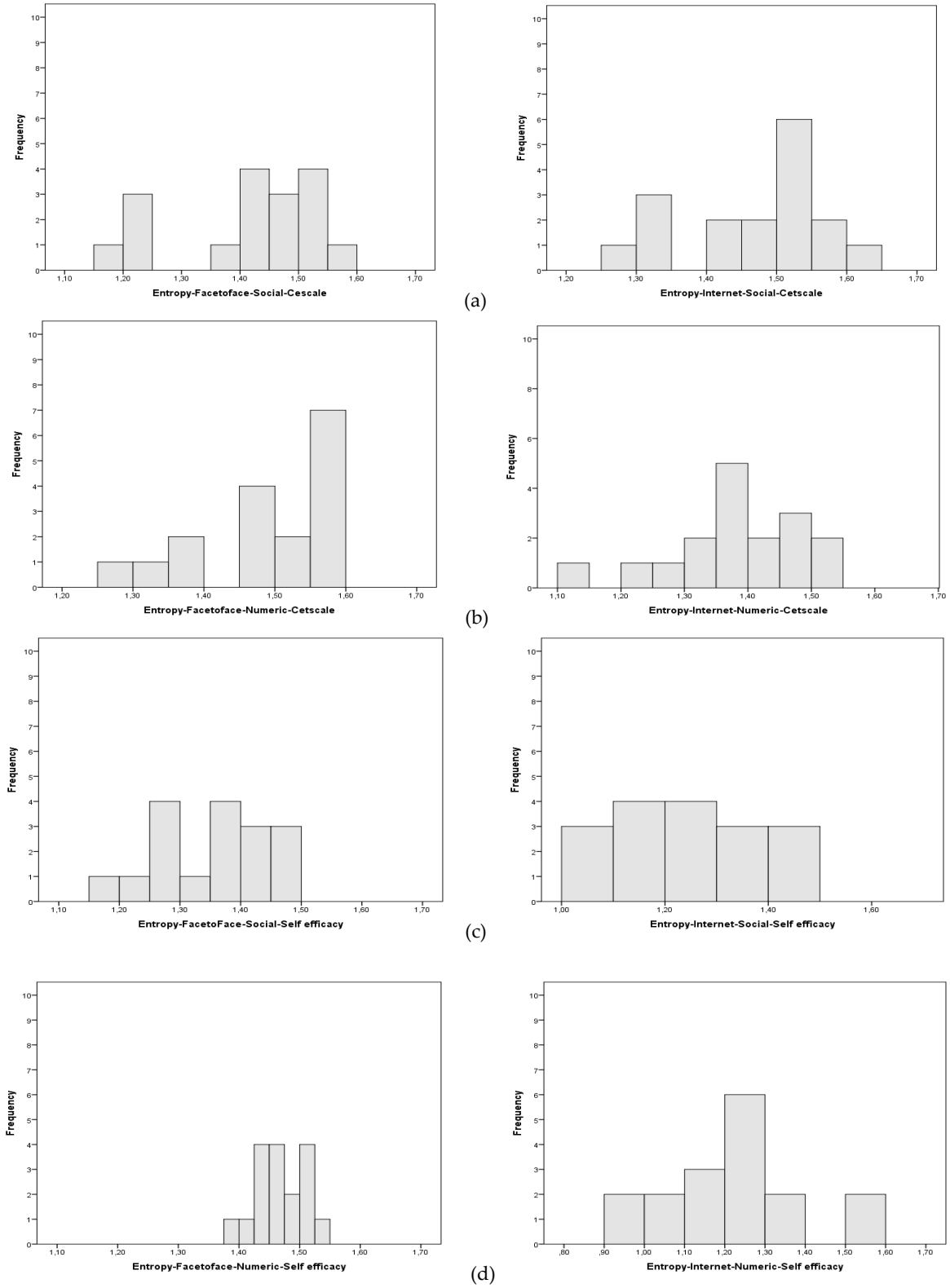

Figure 2. The histograms of the entropies for the scales, the data collection methods and educational background

Another aim of our study is to investigate whether there is any influence of way thinking proclivity of respondents. In order to reach this aim descriptive statistics, t and p values for entropies for each orientation is calculated and presented in Table 4, and histograms are presented in Figure 2.

According to statistical test results on Table 4 and Figure 2, thinking orientation generally produces significant differences; three cases out of four cases entropy measures differ significantly based on method of data collection methods. IB data collection method has less uncertainty or mean entropy than F2F data collection methods for specifically self-efficacy scale. Findings of the study is summarized at Table 5.

Table 5. Summary of the findings

		Scale	
		Cetscale	**Self-efficacy**
Overall	F2F vs Internet	Insignificant difference	Significant difference
		--	Internet confident
Qualitative thinker	F2F vs Internet	Insignificant difference	Significant difference
		--	Internet confident
Quantitative thinker	F2F vs Internet	Significant difference	Significant difference
		Internet confident	Internet confident

6. CONCLUSION AND IMPLICATIONS

IB surveys has been proliferating in social sciences in line with the diffusion of the Internet, however, the equivalence of the IB surveys with traditional F2F surveys remain in question. Though equivalence of different methods is far from the objectives of our current research however this paper focuses on a small aspect of equivalence by utilizing Shannon's entropy measure to compare variability within responses across different survey modes. Shannon's entropy measure vary from 0 to log(n) (n is the number of response alternatives of the scale), while 0 indicates certainty, log(n) indicates exact uncertainty.

This paper compares entropy measures for two scales, for two independent samples and for two data collection methods. Findings also reveal that scales make difference over mean entropy while cetscale does not makes any differences, self-efficacy makes significant differences between IB and F2F data collection methods. In terms of students who have qualitative thinking proclivity, Cetscale is not able to reveal any difference. However, regarding quantitative thinking proclivity cetscale reveals significant differences. For Self-efficacy scale significant differences are revealed.

Entropy measures the level of uncertainty within a given layout in other words entropy tells the level of confidence of the respondents. Based on this perspective of the measurement our findings provide useful implications for interpreting findings, we can argue that IB survey

respondents are more confident in responding, which is in line with Homola et al.,'s (2016) findings.

This research as far we can concerned is the first in Turkey. More researches are needed to make more comprehensive interpretations from different disciplines with different scales. However, the current paper contributes the literature introducing entropy measures for interpreting variability. Furthermore this paper raises awareness about different data collection methods needs to be compared before used interchangeably.

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