ACOUSTICAL PROPERTIES OF CARPETING FIBERS AND TEXTURES

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There are certain factors in the household environment that exert both psychological and physiological influences on family members. One such factor is noise. While family members may become so accustomed to frequent sounds in the home that they exhibit no conscious concern with respect to noise pollution, the meager empirical evidence available suggests that individuals are affected significantly by noise despite the fact that they may not be conscious of or overtly bothered by such.

Hearing is involuntary and when sound exceeds 70 decibels, the automatic reaction of the human nervous system results in a narrowing of the blood vessels—a condition which can be particularly dangerous for people predisposed to heart disease (Braver, 1972). Loud noise produces a sudden excess of adrenalin thereby causing nervousness, anxiety, or fear. Prolonged and consistent exposure to noise levels of 85 decibels or more can produce temporary deafness. Furthermore, noise disturbs the blood vessel apparatus in such a manner that general conduct is affected and deep, sustained thinking is preluded (Jerison, 1959).

Noise in the American home is proving increasingly to be a source of stress, annoyance and fatigue (Mize, Tuten, and Simons, 1966). Many modern appliances can reach a noise level which is highly disturbing to the human ear. In addition, noise from outside the house, as well as that from healthy, active children can bring the total level to a point where medical authorities claim that mental and physical health may be endangered. Although most studies relating noise to high blood pressure and deafness have focused upon persons working in industrial settings, Farr asserted in the Journal of the American Medical Association that homemakers stand to suffer similar consequences

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due to noise in the home. (Farr, 1967).

While sound is a quantitative phenomenon, noise is unwanted sound or distractive sound and, hence, is qualitative and subjective in nature (Farr, 1967). Sound must be above a certain level of intensity, expressed in terms of decibels, to produce a physiological reaction or emotional response in humans. This level is reached at 70 decibels. By comparison, normal conversation is conducted at about 55 decibels. In actuality, the volume of sound an individial can stand varies with the person and the circumstances. Federal law permits an occupational-sound-level exposure of 115 decibels for only 15 minutes a day (OSHA, 1974). Yet, sophisticated applicances, such as a vacuum cleaner can produce sound levels between 50 and 81 decibels (Farr, 1967). Moreover, many such appliances may be operating concurrently, particularly in the kitchen, thus increasing the effective intensity of any one appliance.

One of the first major studies on the effects of household noise was conducted by the Department of Environmental Design at the University of Wisconsin (Westman, 1971). The results of the study served to confirm the suspicions of Farr and other concerned authorities. Dr. Jack C. Westman, Professor of Psychiatry at the University of Wisconsin, concludes that noise is a major contributor to the "tired mother" syndrome which is characterized by headaches, upset stomach, nervous tension, and a feeling of being overwhelmed. This is due to the fact that noise is a constant factor in the home environment, no matter what the homemaker is doing. Westman suggests also that noise can be instrumental in the disintegration of family communication systems thus reducing the pleasure derived from family life.

Modern types of housing construction, numerous types of appliances and equipment, crowding, and housing designs with an open area concept all contribute to noise pollution in the household environment. One way of minimizing noise as an inhibiting factor with respect to satisfying personal and family life is through effective use of household textiles which absorb sound, namely those textiles which are appropriate for floor coverings, window treatments, and upholstery.

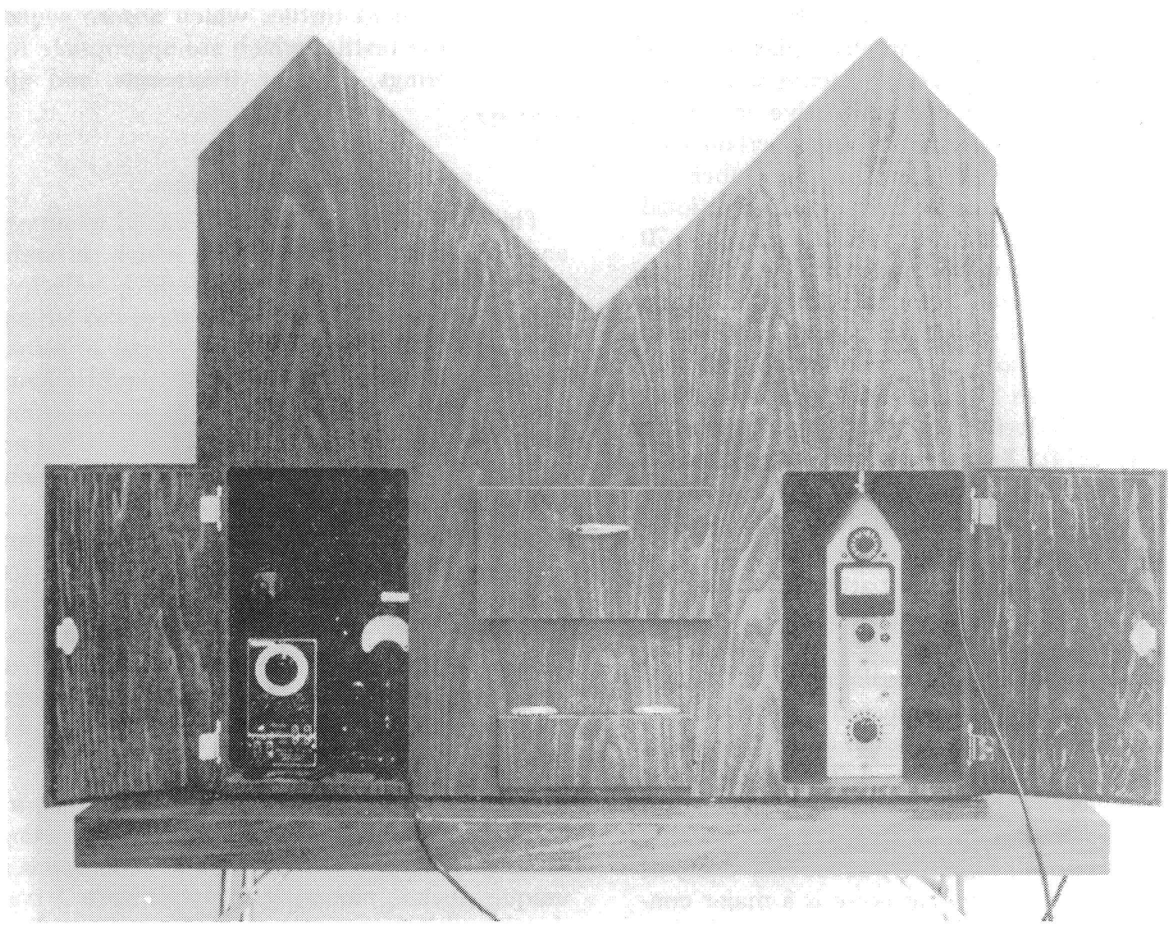
The Research Design

This particular study was designed to survey and to compare the extent to which different carpeting fibers and textures reduce reflective noise as a source of stress, annoyance, and fatigue in the home. Eighteen different types of tufted carpeting with comparable density and backing[1] were studied with respect to high, medium, and low frequency sound absorption. Essentially, four carpeting fibers were tested—acrylic, nylon, polyester, and wool. Level loop, long shag, plush, short shag and sculptured specimens of all fibers were tested with the exception of acrylic for which all textures were not available. Long shag specimens had a pile height of approximately one inch, short shag specimens were one-half inch in pile height, and level loop, plush, and sculptured ranged from one-fourth to one-half inch in pile height.

In order to measure the reflective and absorbative characteristics of various carpeting samples under controlled laboratory conditions, a unique device, named the "Acoustisorb",[2] was developed in cooperation with Engineering Services at Texas Tech University. The theory underlying design of the "Acoustisorb" is that if the reflective properties of a standard hard surface with an area of one square foot can be determined by measurement, then the standard can be replaced by a textile specimen for comparative measurement. To achieve this purpose, an enclosed sound chamber was constructed in the shape of a Y. The area at the junction of the three arms is one square foot and serves as the site for test specimens. The test signal for the energy

[1]Specimens had a primary backing of olefin and a secondary backing of jute.

[2]patent applied for



The "Acoustisorb"

source is furnished by a variable audio oscillator and is metered by an audio voltmeter thereby facilitating control of transducer output. The reflected or transmitted energy is measured with a Bruel and Kjaer sound meter, model no. 2203.

For each type of fiber and each type of texture studied, data collection and analysis focused on low, medium, and high frequency sound absorption. Low frequency sound absorption was defined as the mean decibel value observed at sound levels of 250 hertz and 2000 hertz. Medium frequency sound absorption was defined as the decibel value subsequent to a sound input of 4000 hertz. High frequency sound absorption was denoted as the mean decibel value relevant to sound inputs of 6000 and 8000 hertz. By determining the difference between the standard (control) decibel value and the decibel value relevant to a given carpet specimen and a given sound frequency level, the researchers were able to establish sound absorption efficiency indices (SAEI) for all specimens tested.

Because decibel levels progress-logarithmically, a small change in decibel value can denote a substantial change in the intensity of sound. Generally, a difference of 2 decibels is considered significant variation in analyzing sound data. In this particular study 1.5 dB were considered significant variation between specimens tested an an SAEI of 1.5 or more was considered to denote a specimen with substantial potential for noise abatement. Justification for this level of significance is based on the fact that all dB readings were taken manually as opposed to computerized recording of the data, thereby introducing difficulty in precision reading.

Findings and Conclusions

The "Acoustisorb" developed specifically for the study proved to be a reliable instrument for collecting textile acoustical measurements. Tests can be made quickly on specimens small enough to reduce the economic burden of this type of research. Because the entire device can be placed on a laboratory table facilitating demonstrations to groups of individuals, the instrument would appear to be suitable for classroom use directed toward study of acoustical absorption characteristics of carpeting, upholstery, and drapery textiles as well as those of different wall treatments and insulation materials.

Sound absorption efficiency indices for the eighteen carpet specimens tested reflected several noticeable differences both with respect to fiber and texture. Degree of specimen sound absorption effectiveness at the various frequency levels is shown in Tables 1 and 2.

As indicated in Table 1 for low frequency sound abatement, level loop in in acrylic carpet was significantly more effective than any other texture. Among nylon carpets, textures reflected no significant difference. Among the polyester specimens, level loop was more effective than long shag, plush, or sculptured and short shag performed better than plush. Yet, plush was more effective than short shag in a wool carpet. With respect to texture means, level loop was most effective and sculptured was least effective. However, no significant differences were noted among texture means in terms of reducing low frequency sound and only long shag was found to possess a significant mean SAEI.

Analysis of medium frequency sound absorption data reflected that in an acrylic carpet, level loop was significantly better than plush which, in turn, was better than sculptured. Long shag in nylon and in polyester was better than any other texture. Furthermore, in polyester carpet, level loop and short shag were significantly more effective than plush or sculptured. Among the wool specimens, plush performed significantly better than any other type and long shag and sculptured were far better than short shag. Analysis of texture means indicated that long shag was significantly more effective than any other type and level loop was significantly better than sculptured. All texture means were indicative of a highly significant SAEI.

For high frequency sound reduction, level loop was significantly more effective than either plush or sculptured in an acrylic carpet. In nylon and polyester carpets, long shag was significantly better than any other type while both plush and long shag performed significantly better than sculptured or short shag in wool carpet. Analysis of texture means reflected several significant differences. Long shag was better than any other type, plush and level loop were more effective than sculptured.

In summarizing Table 1, it was concluded that texture does not appear to significantly influence low frequency sound absorption. It does influence significantly, however, both medium and high frequence sound abatement. For both types of noise, long shag is the most effective texture and level loop is significantly better than sculptured.

As revealed in Table 2, low frequency sound is absorbed significantly better if level loop carpet is constructed of an acrylic fiber as opposed to nylon or wool. Furthermore, both level loop and short shag carpets of a polyester fiber are significantly more effective than wool. However, fiber does not appear to influence significantly low frequency sound abatement capacity of

TABLE 1
SOUND ABSORPTION EFFECTIVENESS OF CARPETING TEXTURES

Type of Sound	Type of Fiber	Descriptive Statistic	Performance of Texture (specimen dB value/SAEI)* Level Loop	Long Shag	Plush	Sculptured	Short Shag
Low Freq.	Acrylic		72.25/3.90	**	75.35/ .80	75.05/1.10	**
	Nylon		74.25/1.90	74.45/1.70	74.80/1.35	75.00/1.15	74.90/1.25
	Polyester		73.35/2.80	75.10/1.05	75.40/ .75	75.35/ .80	73.90/2.25
	Wool		75.30/ .85	75.10/1.05	74.05/2.10	75.00/1.15	75.95/ .20
		Mean	73.79/2.36	74.88/1.27	74.90/1.25	75.10/1.05	74.92/1.23
		Rank	1	2	3	5	4
Med. Freq.	Acrylic		72.50/6.70	**	75.90/3.30	78.40/ .80	**
	Nylon		77.40/1.80	73.30/5.90	76.30/2.90	76.60/2.60	76.60/2.60
	Polyester		75.00/4.20	72.00/7.20	77.10/2.10	77.70/1.50	75.50/3.70
	Wool		76.70/2.50	75.50/3.70	73.80/5.40	75.70/3.50	77.20/2.00
		Mean	75.40/3.80	73.60/5.60	75.78/3.43	77.10/2.10	76.43/2.77
		Rank	2	1	3	5	4
High Freq.	Acrylic		62.95/6.00	**	64.90/4.05	68.65/ .30	**
	Nylon		66.95/2.00	63.65/5.30	66.75/2.20	66.10/2.85	67.70/1.25
	Polyester		66.40/2.55	61.75/7.20	65.85/3.10	66.75/2.20	65.05/3.90
	Wool		64.95/4.00	64.15/4.80	63.50/5.45	66.25/2.70	66.75/2.20
		Mean	65.31/3.64	63.18/5.77	65.25/3.70	66.94/2.01	66.50/2.45
		Rank	3	1	2	5	4

* mean dB value for 250 & 2000 hertz equals low frequency performance dB value for 4000 hertz equals medium frequency sound performance mean dB value for 6000 & 8000 hertz equals high frequency sound performance SAEI (sound absorption efficiency index) equals difference between standard dB value and specimen dB value

** specimen unavailable for testing

carpet in a long shag, plush, or sculptured texture.

For both medium and high frequency sound absorption, level loop carpet is more effective in an acrylic fiber. Long shag tends to be preferable in a polyester fiber as does plush carpet in a wool fiber. Nylon is more effective than acrylic in a sculptured carpet while polyester tends to be most desirable in a short shag, particularly for high frequency sound abosrption.

TABLE 2
SOUND ABSORPTION EFFECTIVENESS OF CARPETING FIBERS

Type of Sound	Type of Texture	Descriptive Statistic	Performance of Fiber (specimen dB value/SAEI)* Acrylic	Nylon	Polyester	Wool
Low Freq.	Level Loop		72.25/3.90	74.25/1.90	73.35/2.80	75.30/ .85
	Long Shag		**	74.45/1.70	75.10/1.05	75.10/1.05
	Plush		75.35/ .80	74.80/1.35	75.40/ .75	74.05/2.10
	Sculptured		75.05/1.10	75.00/1.15	75.35/ .80	75.00/1.15
	Short Shag		**	74.90/1.25	73.90/2.25	75.95/ .20
		Mean	74.22/1.93	74.68/1.47	74.62/1.53	75.08/1.07
		Rank	1	3	2	4
Medium Freq.	Level Loop		72.50/6.70	77.40/1.80	75.00/4.20	76.70/2.50
	Long Shag		**	73.30/5.90	72.00/7.20	75.50/3.70
	Plush		75.90/3.30	76.30/2.90	77.10/2.10	73.80/5.40
	Sculptured		78.40/ .80	76.60/2.60	77.70/1.50	75.70/3.50
	Short Shag		**	76.60/2.60	75.50/3.70	77.20/2.00
		Mean	75.60/3.60	76.04/3.16	75.46/3.74	75.78/3.42
		Rank	2	4	1	3
High Freq.	Level Loop		62.95/6.00	66.95/2.00	66.40/2.55	64.95/4.00
	Long Shag		**	63.65/5.30	61.75/7.20	64.15/4.80
	Plush		64.90/4.05	66.75/2.20	65.85/3.10	63.50/5.45
	Sculptured		68.65/ .30	66.10/2.85	66.75/2.20	66.25/2.70
	Short Shag		**	67.70/1.25	65.05/3.90	66.75/2.20
		Mean	65.50/3.45	66.23/2.72	65.16/3.79	65.12/3.83
		Rank	3	4	2	1

* mean dB value for 250 & 2000 hertz equals low frequency sound performance dB value for 4000 hertz equals medium frequency sound performance mean dB value for 6000 & 8000 hertz equals high frequency sound performance SAEI (sound absorption efficiency index) equals difference between standard dB value and specimen dB value

** specimen unavailable for testing

Tables 3, 4, and 5 summarize performance of textures and fibers with respect to sound abatement. As indicated in these tables, performance of both tends to vary according to type of sound. With respect to texture, level loop is most effective in absorbing low frequency sound while long

TABLE 3
RANKING OF TEXTURES ACCORDING TO SOUND ABSORPTION EFFECTIVENESS

Ranking of Sound Absorp. Effec.		Low Freq. Sound Absorp. ($\bar{X}$ dB value)		Med. Freq. Sound Absorp. ($\bar{X}$ dB value)		High Freq. Sound Absorp. ($\bar{X}$ dB value)		*Overall Sound Absorption
1	(most effective)	level loop	73.79	long shag	73.60	long shag	63.18	long shag
2		long shag	74.88	level loop	75.40	plush	65.25	level loop
3		plush	74.90	plush	75.78	level loop	65.31	plush
4		short shag	74.92	short shag	76.43	short shag	66.50	short shag
5	(least effective)	sculptured	75.10	sculptured	77.10	sculptured	66.94	sculptured

*Σ(low, medium, and high frequency dB values)÷3

TABLE 4
RANKING OF FIBERS ACCORDING TO SOUND ABSORPTION EFFECTIVENESS

Ranking of Sound Absorp. Effectiveness		Low Freq. Sound Absorp. ($\bar{X}$ dB value)		Med. Freq. Sound Absorp. ($\bar{X}$ dB value)		High Freq. Sound Absorp. ($\bar{X}$ dB value)		*Overall Sound Absorp.
1	(most effective)	acrylic	74.22	polyester	75.46	wool	65.12	polyester
2		polyester	74.62	acrylic	75.60	polyester	65.16	acrylic
3		nylon	74.68	wool	75.78	acrylic	65.50	wool
4	(least effective)	wool	75.08	nylon	76.04	nylon	66.23	nylon

*Σ(low, medium and high frequency dB values)÷3

shag is decidedly more desirable for medium and high frequency sound abatement. A sculptured texture is least desirable regardless of type of noise. Performance of fiber is more difficult to generalize. Acrylic is most effective for low frequency sound absorption, polyester for medium frequency sound, and wool for high frequency sound. Nylon is least effective for medium and high frequency sound absorption and is next to least effective for low frequency sound. With respect to texture-fiber combination, polyester long shag performs most effectively on an overall basis while nylon sculptured appears to be least effective.

TABLE 5
SOUND ABSORPTION EFFECTIVENESS OF TEXTURE-FIBER COMBINATIONS

Degree of Effectiveness	Low Frequency Sound Absorption	Medium Frequency Sound Absorption	High Frequency Sound Absorption	Overall Sound Absorption
Most Effective	acrylic level loop	polyester long shag	wool long shag	polyester long shag
Least Effective	wool sculptured	nylon sculptured	nylon sculptured	nylon sculptured

Implications

Professionals and individual consumers concerned with the psychophysical effects of household noise need to be advised of the extent to which variations exist among the different carpeting fibers and textures with respect to noise abatement efficiency. Housing and consumer education programs must assume responsibility for imparting this type of information to interested individuals. In addition, carpeting manufacturers need to be encouraged to provide labeling information indicative of the acoustical properties of a given product. With valid information of this nature at his disposal, the consumer will then be in a position to select carpeting which is most appropriate for minimizing sound levels within the different areas of a house. Finally, legislative standards need to be established regarding carpeting and other housing construction materials which possess significant potential for household noise abatement.

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